67-FM-64

NL

05952-H199-RO-00

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MSC INTERNAL NOTE NO. 67-FM-64

1 MAY 1967

EFFECT OF LAUNCH VEHICLE DESTRUCT ACTION ON SERVICE MODULE, LUNAR MODULE, AND SPACECRAFT LM ADAPTER FOR MISSION AS-504

By Apollo Engineering Operations Department,
TRW Systems

Prepared by C. D. Faust

MISSION PLANNING AND ANALYSIS DIVISION

MANNED SPACECRAFT CENTER

HOUSTON, TEXAS

(NASA-TM-X-69770) EFFECT OF LAUNCH VEHICLE DESTRUCT ACTION ON SERVICE MODULE, LUNAR MODULE, AND SPACECRAFT LM ADAPTER FOR MISSION AS-504 (NASA) 65 p

N74-70629

Unclas

00/99 16175

05952-H199-R0-00

MSC INTERNAL NOTE NO. 67-FM-64

EFFECT OF LAUNCH VEHICLE DESTRUCT ACTION ON SERVICE MODULE, LUNAR MODULE, AND SPACECRAFT LM ADAPTER FOR MISSION AS-504

By Apollo Engineering Operations Department,
TRW Systems

1 MAY 1967

MISSION PLANNING AND ANALYSIS DIVISION
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

Approved by R. E. McAdams
R. E. McAdams, Head
Flight Studies Section
NASA/MSC

Approved by A. J. Rinaldi
A. J. Rinaldi, Manager
Apollo Engineering Operations
Department
TRW Systems

Approved by C. R. Hicks Jr.
C. R. Hicks, Jr., Chief
Flight Analysis Branch
NASA/MSC

Approved by L. Wilcox
L. F. Wilcox,
Manned Spacecraft Systems
Laboratory
TRW Systems

Approved by J. P. Mayer
J. P. Mayer, Chief
Mission Planning and Analysis
Division
NASA/MSC

Approved by B. J. Gordon
B. J. Gordon, Manager
Systems Analysis and Operations
TRW Systems

ABSTRACT

This report is submitted to the National Aeronautics and Space Administration, Manned Spacecraft Center by TRW Systems in accordance with Task MSC/TRW A-4, Subtask A-4.1, of the Apollo Mission Trajectory Control Program, Contract NAS 9-4810. The purpose of this analysis is to determine the effect of launch vehicle destruct action on the Service Module, Lunar Module, and Spacecraft LM Adapter following an abort of the mission. In particular, this report is concerned only with Mission AS-504 and its associated configuration and trajectory.

CONTENTS

	Page
1. INTRODUCTION AND SUMMARY	1-1
1.1 Introduction	1-1
1.2 Summary	1-1
2. ABORT PHASES	2-1
3. ENVIRONMENT	3-1
4. STRUCTURAL BREAKUP	4-1
5. VELOCITY OF PIECES	5-1
6. LETHAL AREAS	6-1
APPENDIXES	
A SPACECRAFT CONFIGURATION FOR MISSION AS-504	A-1
B STRUCTURAL CAPABILITY OF SPACECRAFT ELEMENTS	B-1
REFERENCES	R-1

ILLUSTRATIONS

		Page
3-1	Selected Stations for Overpressure Calculations	3-3
4-1	Saturn/Apollo Configuration for Mission AS-504	4-4
4-2	Overpressure Environment and Failure Point for LM Descent Stage, Aft Deck, Station 1	4-5
4-3	Overpressure Environment and Failure Points for SLA Lower Panels and LM Descent Stage Panels, Station 2	4-6
4-4	Overpressure Environment and Failure Points for SLA Lower Panels and LM Descent Stage Panels, Station 3	4-7
4-5	Overpressure Environment and Failure Points for SLA Upper Panels and LM Ascent Stage Panels, Station 4	4-8
4-6	Overpressure Environment and Failure Points for SLA Upper Panels and LM Ascent Stage Panels, Station 5	4-9
4-7	Overpressure Environment and Failure Point for SM Aft Bulkhead, Station 6	4-10
4-8	Overpressure Environment and Failure Point for SM Panels, Station 7	4-11
4-9	Overpressure Environment and Failure Point for SM Panels, Station 8	4-12
A-1	Service Module Outboard Configuration	A-2
A-2	Service Module Structure and Systems Equipment	A-2
A-3	Lunar Module	A-3
A-4	Spacecraft LM Adapter	A-4
B-1	Lunar Module Idealized Outer Panels	B-3
B-2	Lunar Module Ascent Stage Inner Structure Panels	B-4
B-3	Lunar Module Descent Stage Inner Structure Panels	B-5

TABLES

		Page
6-1	Results of Breakup from Lift-off to 95,000 feet	6-2
6-2	Results of Breakup from 95,000 feet to 115,000 feet	6-12
6-3	Results of Breakup from 115,000 feet to 125,000 feet	6-21
6-4	Results of Breakup from 125,000 feet to 160,000 feet	6-29
6-5	Results of Breakup from 160,000 feet to LES Jettison	6-29
6-6	Results of Breakup from LES Jettison to Orbital Insertion	6-30

1. INTRODUCTION AND SUMMARY

1.1 INTRODUCTION

This report is submitted to the National Aeronautics and Space Administration, Manned Spacecraft Center by TRW Systems in accordance with Task MSC/TRW A-4, Subtask A-4.1, of the Apollo Mission Trajectory Control Program, Contract NAS 9-4810. The purpose of the analysis is to determine the effect of launch vehicle destruct action on the Service Module (SM), Lunar Module (LM), and Spacecraft LM Adapter (SLA).

Mission AS-504 of the Saturn/Apollo System uses the Block II Command and Service Module configuration. The Saturn V launch vehicle (Figure 4-1) will be used to boost the Command Module, Service Module, LM-4, and third stage S-IVB into orbit.

This report presents the destruct induced environment realized by the spacecraft, the mode of structural breakup, and the weight, lethal areas, and initial velocities of the resulting pieces. Appendix A presents a description of the spacecraft configuration for Mission AS-504. Appendix B contains the analytical predictions of the structural capabilities of the spacecraft components.

This report is similar in format to the report on Mission AS-206 in Reference 1. However, the spacecraft configuration for Mission AS-504 is significantly different from that of Mission AS-206.

1.2 SUMMARY

This analysis considered only the ascent portion of the powered flight up to orbital insertion for Mission AS-504. An abort of the mission during this time will be initiated if the booster malfunctions or an impending failure is indicated. The range safety officer will destroy the booster, subsequent to the abort and dependent upon the time of flight, if the booster and remaining spacecraft components appear to violate range safety constraints. This investigation analyzed the effect of such a destruction and explosion on the SM, LM, and SLA. Effects of the destruct action upon the escaping spacecraft configuration (LES/CM or CSM) were not evaluated.

The analysis presented in this report considered two spacecraft configurations for an abort during the powered flight. For flight from lift-off to launch escape system jettison, the remaining spacecraft configuration consisted of the SM, LM, and SLA. The second configuration was for flight from LES jettison to orbital insertion and consisted of the LM and SLA only. The SM was aborted along with the CM if an abort was initiated during that phase of flight (SPS abort).

For the first spacecraft configuration considered, SM, SLA, and LM, it was established that the overpressure would fail the SM aft bulkhead at any altitude from lift-off to 125, 000 feet. Failure of the aft bulkhead will very probably cause the SPS engine to penetrate and explode the lower SPS helium tank. This explosion will then completely destroy the SM, SLA, and partially destroy the LM. It has also been established that the overpressure alone could completely break up the LM ascent stage at any altitude from lift-off to 95, 000 feet. The LM descent stage would completely break up at any altitude from lift-off to 115, 000 feet. A partial breakup of the LM ascent stage (outer skin failure only) was found to occur from 95, 000 feet to 130, 000 feet. The LM descent stage was found to partially break up (outer skin failure only) from 115, 000 feet to 160, 000 feet. Therefore, complete destruction of the SM, SLA, and LM could occur at any altitude from lift-off to 95, 000 feet. It has been estimated that 832 pieces of debris would result from this destruction, presenting a total lethal area of 14, 680 square feet. Complete destruction of the SM, SLA, and LM descent stage, and partial destruction of the LM ascent stage may occur from 95, 000 feet to 115, 000 feet. This destruction results in 726 pieces and a total lethal area of 13, 840 square feet. A partial breakup of the LM (both stages) and complete destruction of the SM and SLA, could occur from 115, 000 feet to 125, 000 feet. This breakup represent 647 pieces of debris and a total lethal area of 13, 290 square feet. From 125, 000 feet to 160, 000 feet the LM descent stage partially fails and the remaining portions do not. This represents 65 pieces of debris with a total lethal area of 2, 010 square feet. Above 160, 000 feet to LES jettison no breakup occurs. Thus the remaining spacecraft components present one piece of debris with a total lethal area of 1, 000 square feet.

If destruct action occurs after LES jettison, it has been established that no breakup will occur due to the overpressure. For this analysis it has been assumed that the four upper SLA panels break away from the rest of the structure. Therefore, this situation represents 5 pieces of debris with 2,520 square feet of lethal area.

2. ABORT PHASES

The sequence of events associated with an abort of Mission AS-504 and the removal of the launch-escape subsystem/command module (LES/CM) or command service module (CSM) is dependent upon both the time of flight at which abort is required and the decisions of the range safety officer. The effect of launch vehicle destruct action on the remaining portions of the spacecraft is strongly dependent upon the altitude and other trajectory parameters. These significant trajectory data were obtained from References 2 and 3.

The following abort and destruct ground rules were assumed for this analysis:

a) During the first 40 seconds of flight, destruct action will definitely take place following an LES abort.

b) Subsequent to any abort during the powered flight, up to insertion into orbit, the destruct signal will be sent if the booster and remaining spacecraft elements appear to violate range safety constraints.

c) An SPS abort can occur any time after LES jettison has taken place, approximately 35 seconds after S-IC cutoff. (Reference 4).

Therefore, based on these ground rules, the effects of launch vehicle destruct action may be experienced during any part of the booster powered flight until orbital insertion. A booster failure could also result in essentially the same environment as the intentional destruct.

3. ENVIRONMENT

Destruct action can be taken on the S-IC, S-II, and S-IVB stages of the Saturn V launch vehicle. This study considered only the effects of destruct action on the S-IVB stage. This selection was based on comparing preliminary calculations of the effects of destruct action on the S-II and S-IVB stages for the same station and altitude and on the relative proximity of the stages to the spacecraft.

a) The S-IVB stage will always be involved in the destruct action regardless of the flight time.

b) The S-IVB stage is significantly closer to the spacecraft. (For the station investigated the S-IVB was three times closer than the S-II.)

c) The resulting incident shock overpressure for the S-IVB was an order of magnitude greater than for the S-II. (0.8 psi compared to 0.08 psi)

d) The resulting reflected shock overpressure for the S-IVB was six times greater than for the S-II. (38 psi compared 6 psi)

Thus the S-IVB stage yielded a more severe destruction environment.

The destruction system for the S-IVB stage consists of explosive harness assemblies and linear shape charges (Reference 5). This system splits the liquid hydrogen and oxygen tanks to disperse the propellants to avoid a safety hazard. A more detailed explanation of this destruction system is given in Reference 6. For this analysis, a one-percent mix of the available fuel and oxidizer was assumed. This assumption was based on the results of the study made in Reference 7.

The environment induced on the remaining spacecraft elements, as a result of destruct action, consists primarily of a large overpressure. The overpressure is strongly dependent upon the following:

a) Amount of propellants in the stage

b) Distance from the assumed point source of the explosion (i.e., the liquid oxygen (LOX) tank base)

c) Altitude at which destruction takes place

The aerodynamic forces exerted on the spacecraft are significantly smaller than those associated with the destruct environment. From Reference 8, the maximum crush pressure on the SM during separation at maximum dynamic pressure is 4 psi. When the Launch Escape Vehicle-SM separation distance is approximately 26 feet (2 diameters), the maximum burst pressure is 9 psi (Reference 8). Since the overpressure on the SM is approximately 40 psi, the aerodynamic forces have been neglected. The thermal effects have also been neglected, since the thermal pulse associated with the destruct action is assumed to be too short to degrade the spacecraft structural capabilities significantly.

For this analysis, it was assumed that when the destruct action took place the remaining portions of the spacecraft were still intact with the booster. Eight stations were selected at which the overpressure created by this destruct action was determined. These eight stations are as follows:

1) LM descent stage aft deck (534 in. from the explosion center)
2) LM descent stage outer structure and SLA lower panels (566 in. from the explosion center)
3) LM descent stage outer structure and SLA lower panels (599 in. from the explosion center)
4) LM ascent stage outer structure and SLA upper panels (649 in. from the explosion center)
5) LM ascent stage outer structure and SLA upper panels (679 in. from the explosion center)
6) SM aft bulkhead (848 in. from the explosion center)
7) SM outer panels (880 in. from the explosion center)
8) SM outer panels (1003 in. from the explosion center)

The above stations are shown in Figure 3-1. The overpressure environments for each station are presented in Figures 4-2 through 4-9 for any altitude from lift-off to orbital insertion. The method of calculating the overpressures and the three altitude regions shown in Figures 4-2 through 4-9 are explained in more detail in Reference 6.

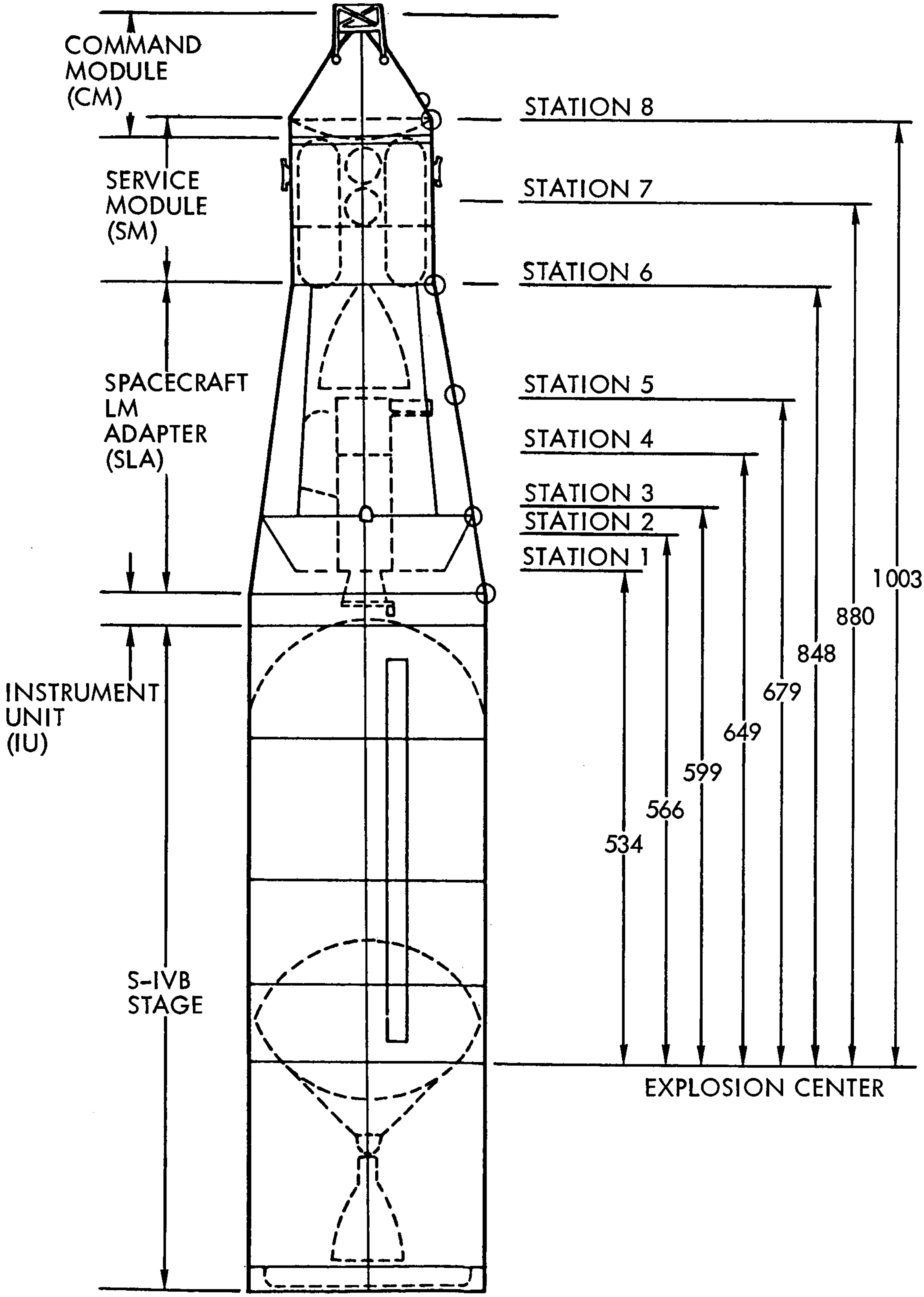

Figure 3-1. Selected Stations for Overpressure Calculations

4. STRUCTURAL BREAKUP

The structural breakup of the remaining spacecraft elements after an abort is highly dependent upon the Saturn/Apollo configuration used for Mission AS-504 (Figure 4-1). The spacecraft consists of Block II Command and Service Modules, a Spacecraft LM Adapter, and a Lunar Module (LM-4). The Apollo spacecraft configuration is presented in more detail in Appendix A of this report.

The minimum overpressures necessary to fail specific spacecraft components are shown in Figures 4-2 through 4-9. These failure overpressures are based on the ultimate structural capability of the spacecraft components neglecting any thermal effects. The failure overpressure calculations are described in Appendix B of this report.

The effects of launch vehicle destruct action were considered only on the SM, LM, and SLA. The escaping spacecraft configuration (LES/CM or CSM) was not analyzed in this study. The breakup mode was assumed to be induced by the explosion of the S-IVB propellants. This explosion causes an overpressure to rupture the LH_2 tank dome and pass through and around the IU. The overpressure then engulfs the LM, SLA, and SM. It was assumed that failure of the SM aft bulkhead would cause the SPS engine to penetrate and explode the lower pressurized SPS helium tank. Sufficient energy would then be created to cause complete breakup of the SM and the SLA panels and a partial breakup of the LM. In addition to the lower SPS helium tank, the SPS propellant tanks rupture, but since the propellants are hypergolic, they should not be expected to explode. However, if these propellants mix with the S-IVB stage liquid hydrogen and oxygen propellants, an explosive mixture could result. The pressurized helium tanks in the LM were assumed to remain intact. The explosion of these pressurized tanks would increase both the number of pieces and the initial velocities imparted to the pieces. There is a low probability of the tanks being penetrated and exploded because of the thickness of the shell and their location in the LM.

Figures 4-2 through 4-9 show that as a result of the overpressure, the following conclusions can be made with regard to the spacecraft breakup:

a) The SM outer panels will fail if destruct action occurs at any altitude from lift-off up to 95,000 feet.

b) The SM aft bulkhead will fail if destruct action occurs at any altitude from lift-off up to 125,000 feet.

c) The SLA upper panels will fail if destruct action occurs at any altitude from lift-off up to 115,000 feet.

d) The SLA lower panels will fail if destruct action occurs at any altitude from lift-off up to 115,000 feet.

e) The LM ascent stage will fail if destruct action occurs at any altitude from lift-off up to 95,000 feet. Partial failure (outer skin failure only) of the LM ascent stage will occur from 95,000 feet to 130,000 feet.

f) The LM descent stage will fail if destruct action occurs at any altitude from lift-off up to 115,000 feet. A partial breakup (outer skin failure only) of the descent stage will occur from 115,000 feet to 160,000 feet.

A partial breakup of the LM, where only the outer skin fails, results in a reduction of the total number of pieces. Many of the pieces remain attached to the descent stage or inside the pressurized midsection and crew compartment.

It is difficult to analytically determine the nature of the breakup because the breakup mode was assumed to be induced by explosion. However, estimates were made as to the number, weights, and sizes of the resulting pieces. Tables 6-1 through 6-6 give these estimates in detail. The list shown below, gives a summary of the altitude ranges considered for breakup and the resulting pieces of debris.

a) Lift-off to 95,000 feet, 832 pieces of debris

b) 95,000 feet to 115,000 feet, 726 pieces of debris

c) 115,000 feet to 125,000 feet, 647 pieces of debris

d) 125,000 feet to 160,000 feet, 65 pieces of debris

e) 160,000 feet to LES Jettison, 1 piece of debris

f) LES Jettison to orbital insertion, 5 pieces of debris

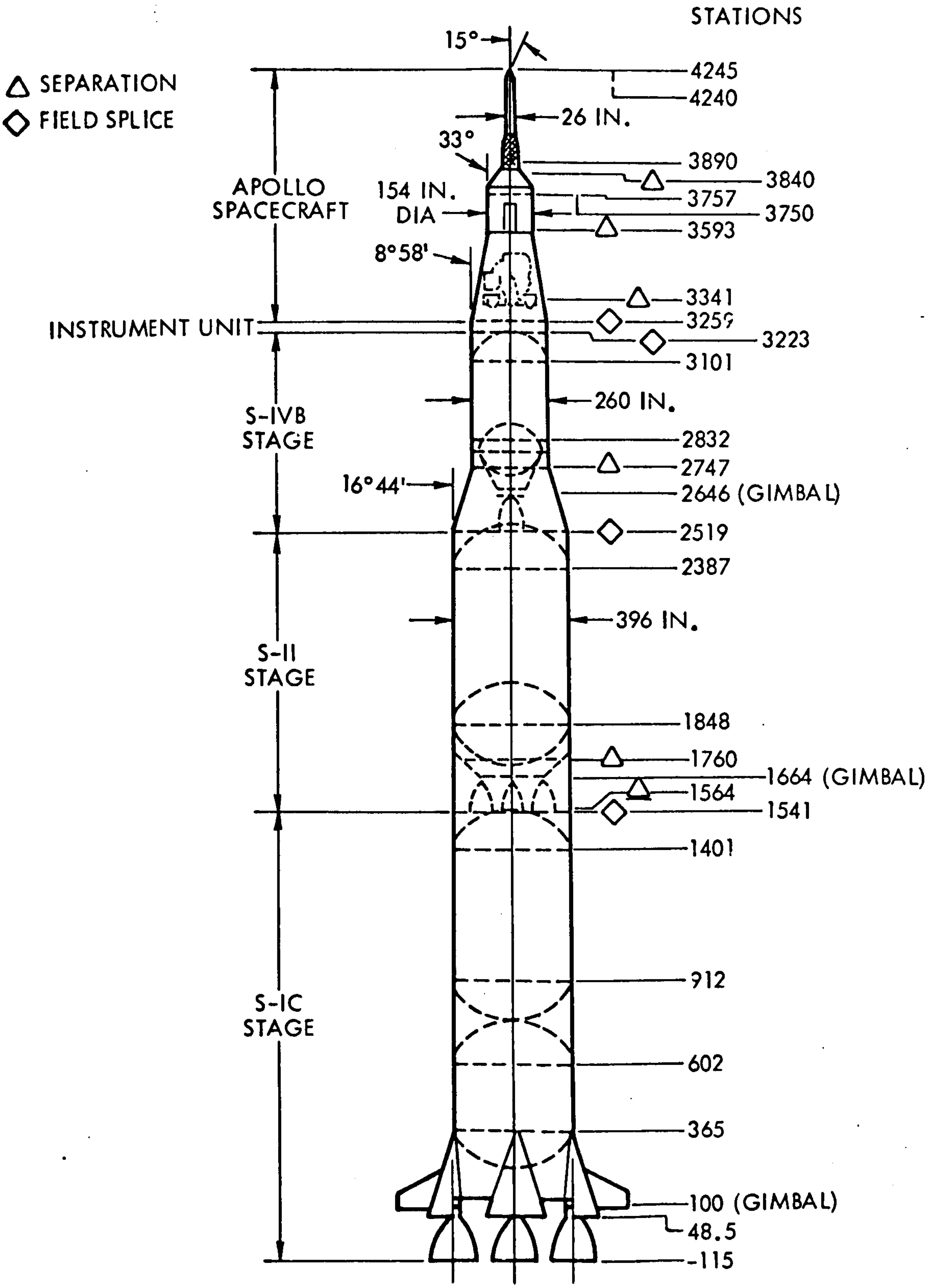

Figure 4-1. Saturn/Apollo Configuration for Mission AS-504

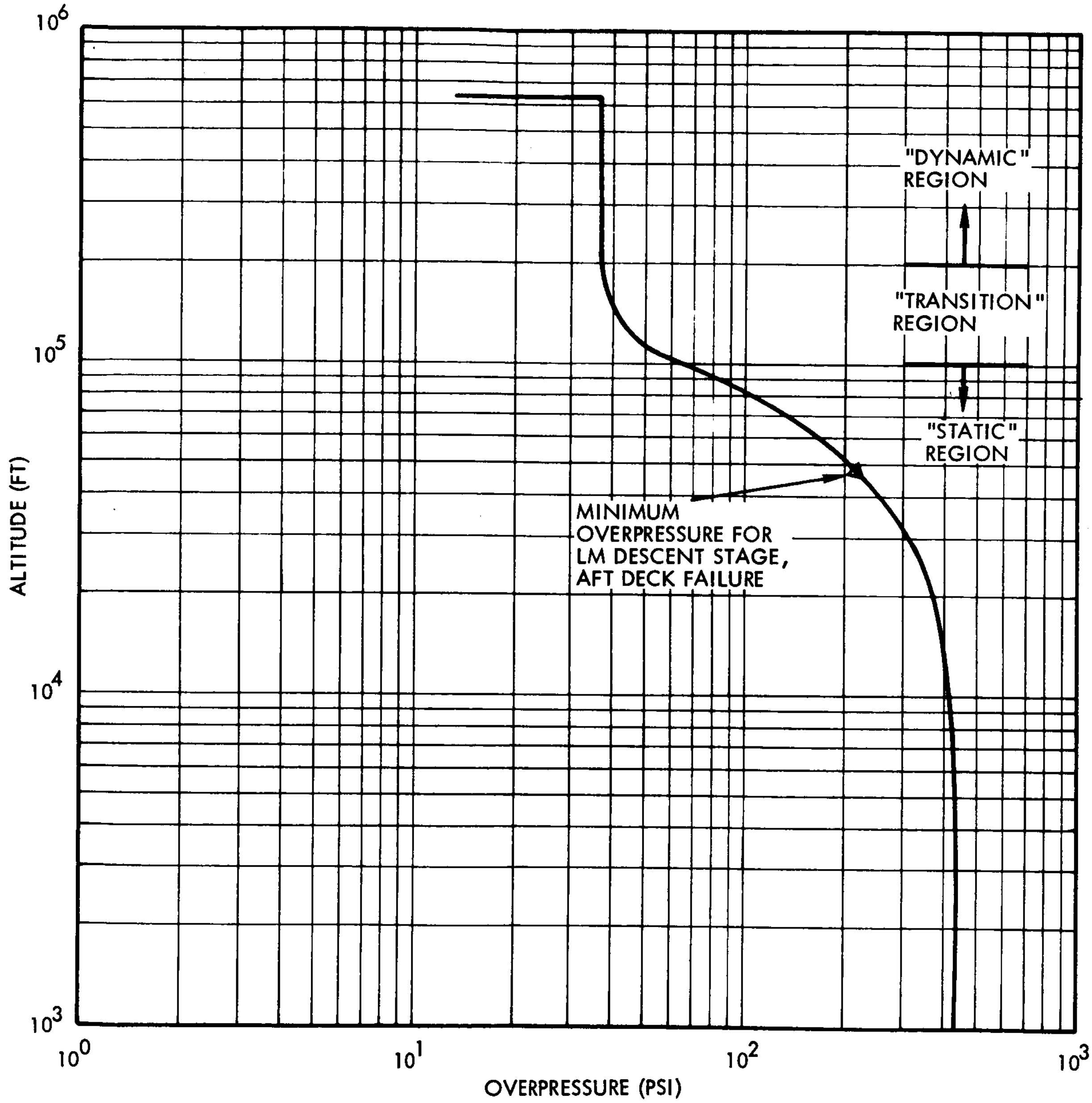

Figure 4-2. Overpressure Environment and Failure Point for LM Descent Stage, Aft Deck, Station 1

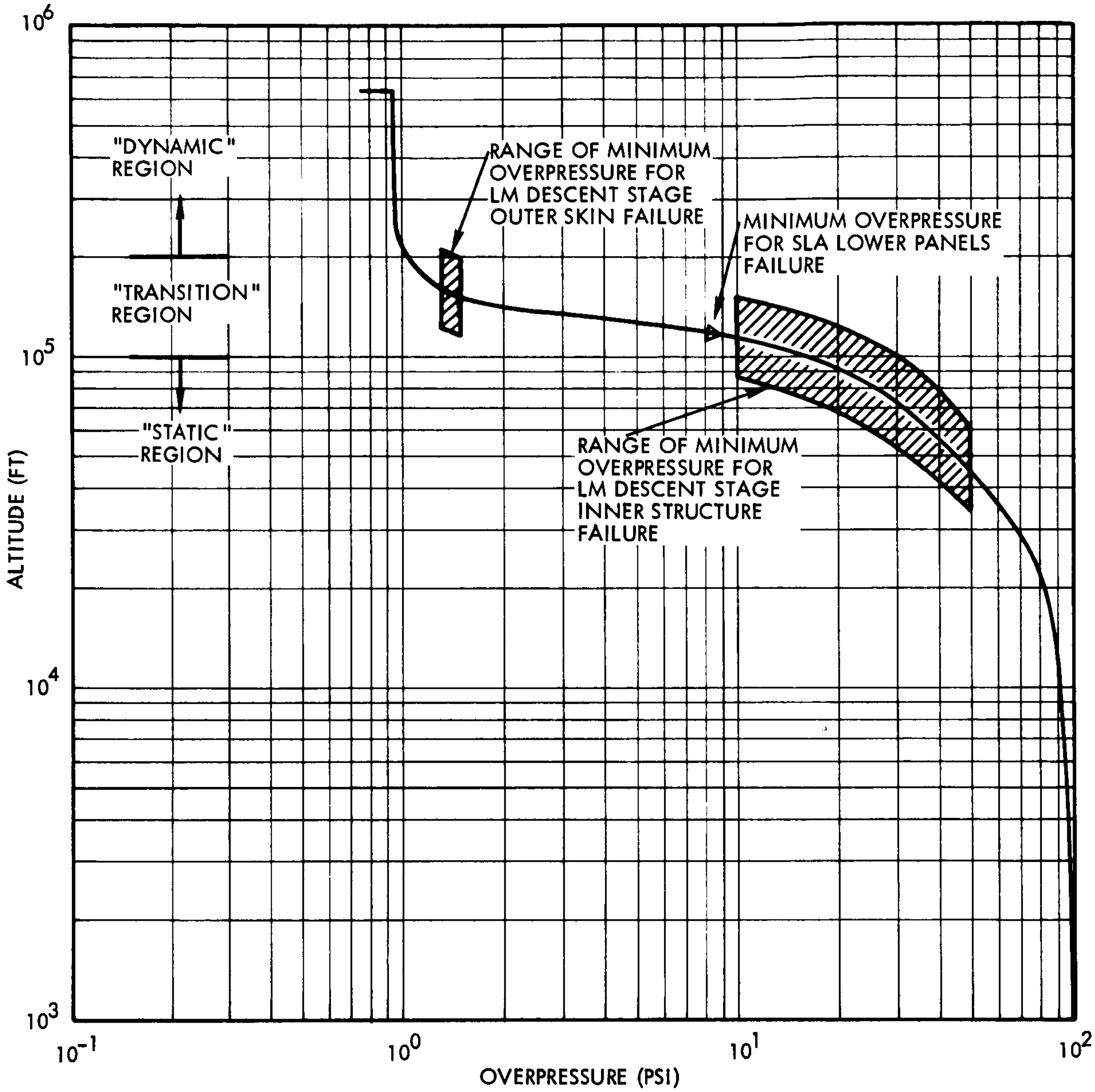

Figure 4-3. Overpressure Environment and Failure Points for SLA Lower Panels and LM Descent Stage Panels, Station 2

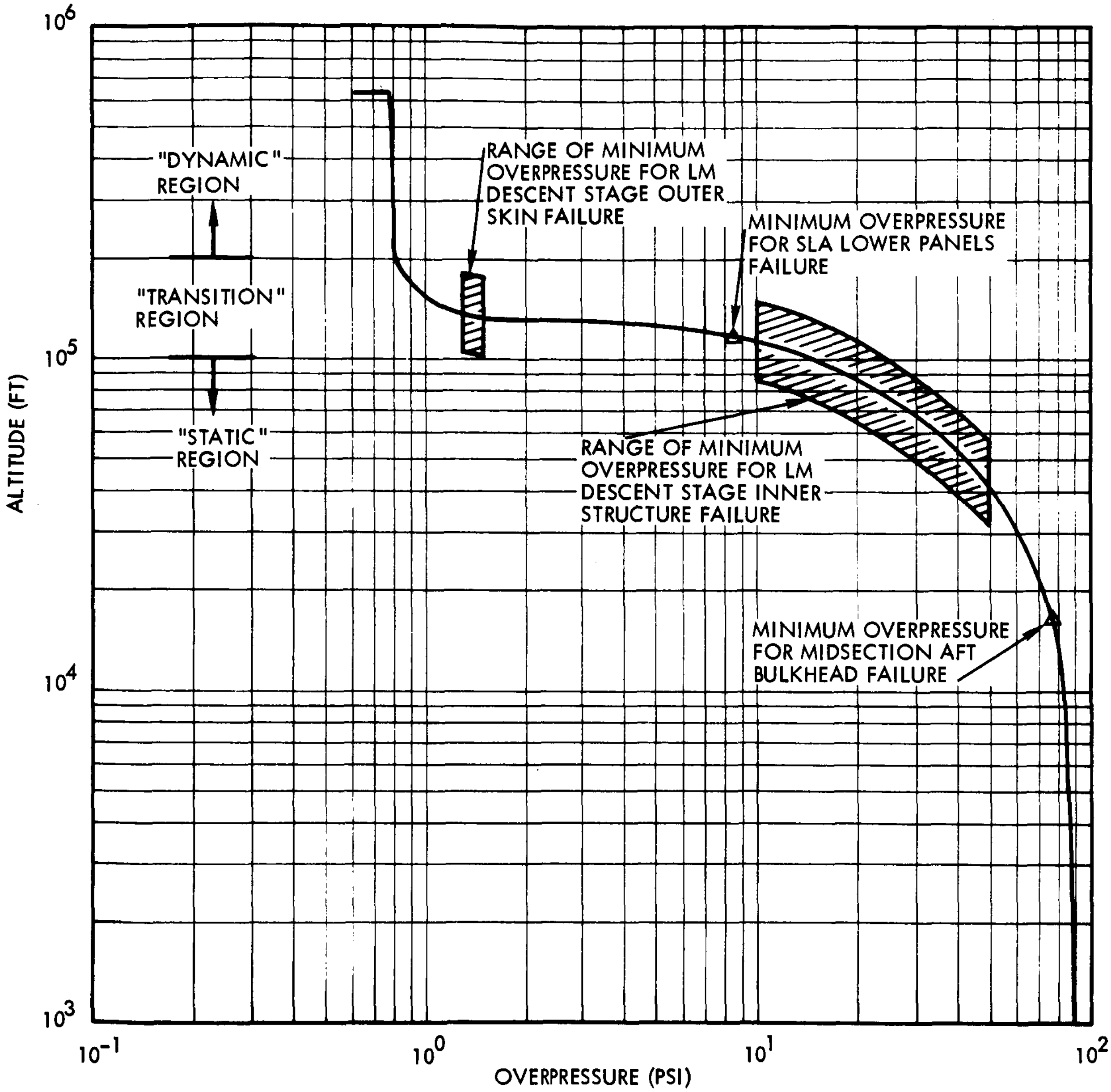

Figure 4-4. Overpressure Environment and Failure Points for SLA Lower Panels and LM Descent Stage Panels, Station 3

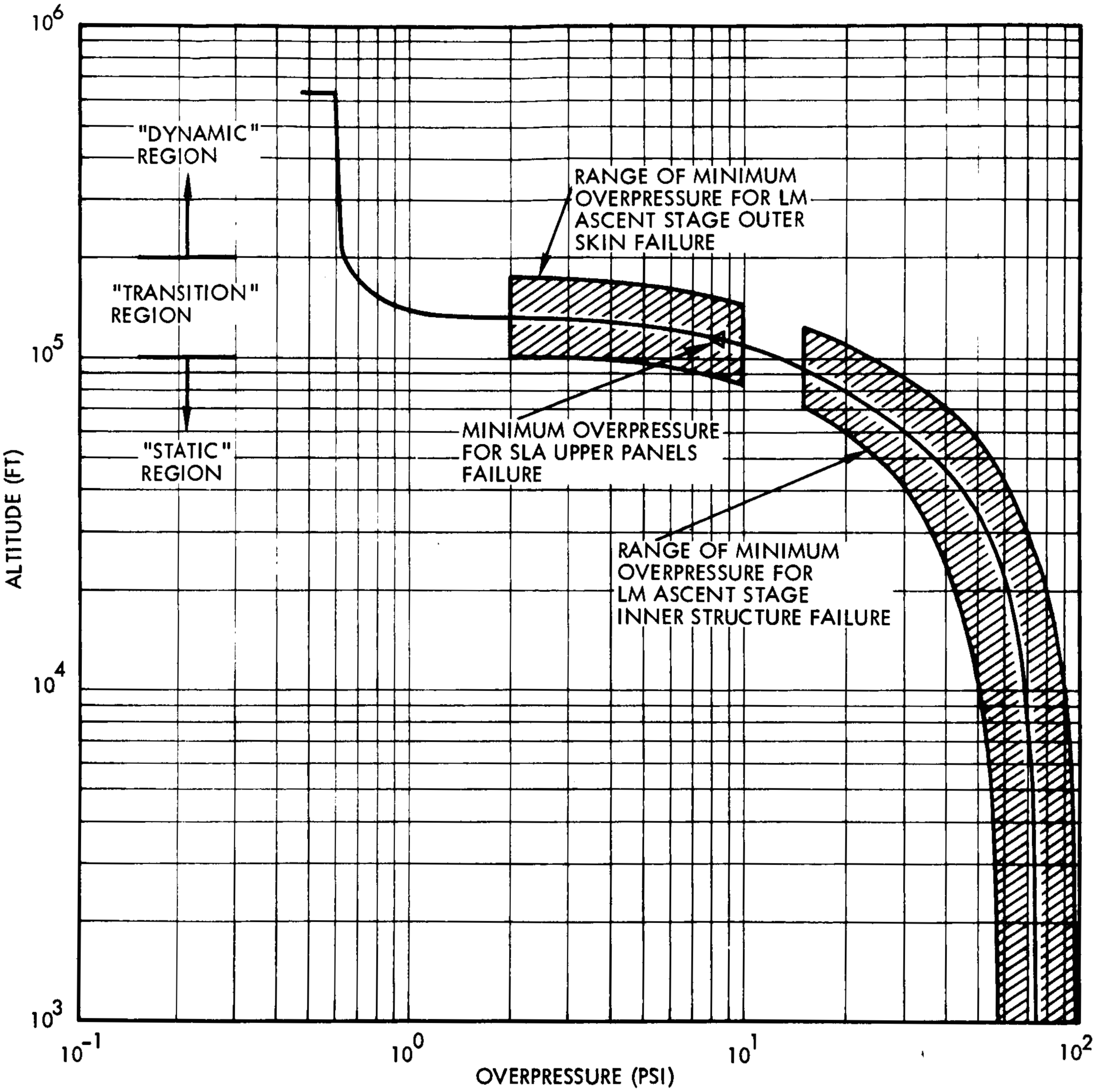

Figure 4-5. Overpressure Environment and Failure Points for SLA Upper Panels and LM Ascent Stage Panels, Station 4

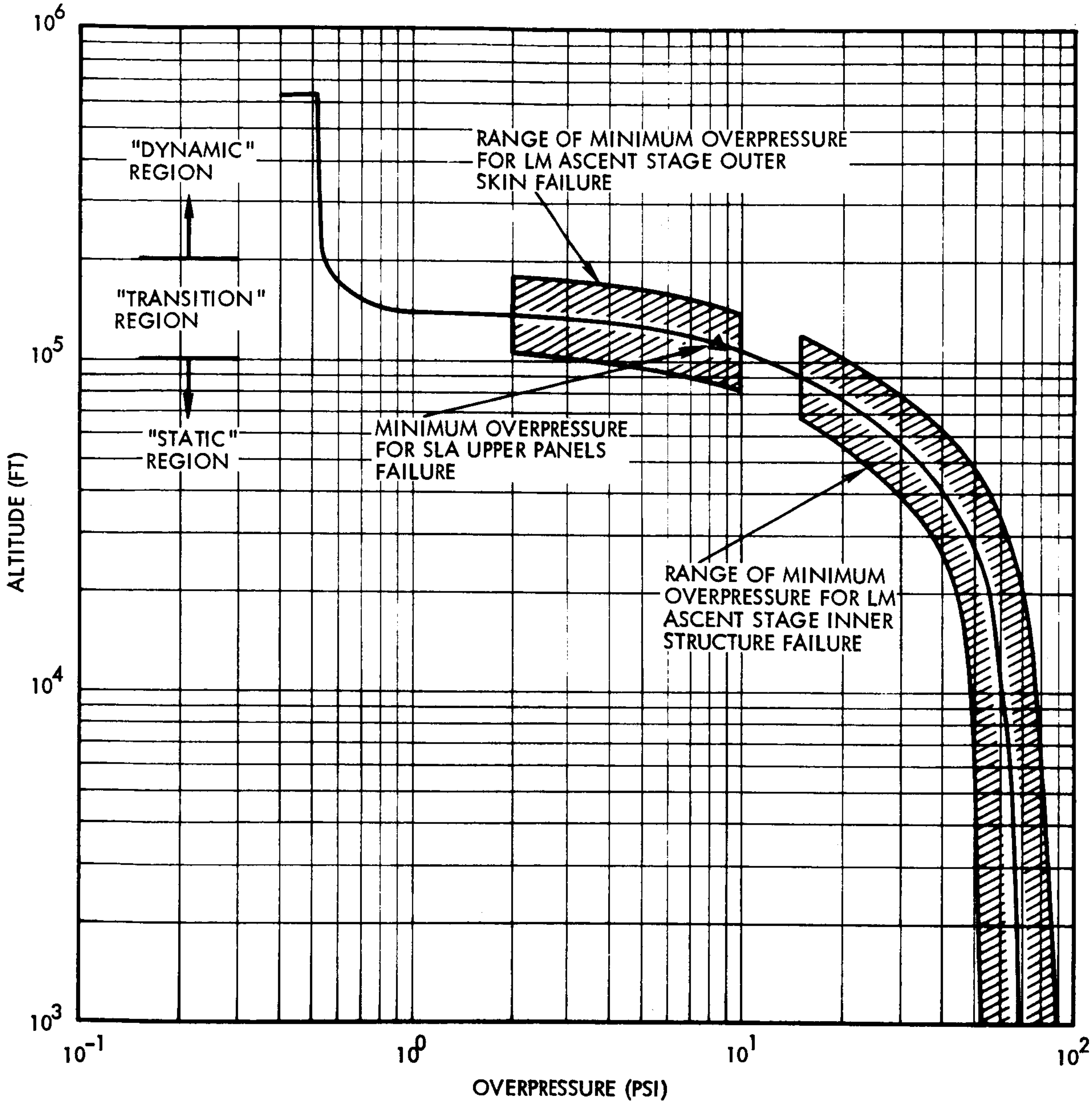

Figure 4-6. Overpressure Environment and Failure Points for SLA Upper Panels and LM Ascent Stage Panels, Station 5

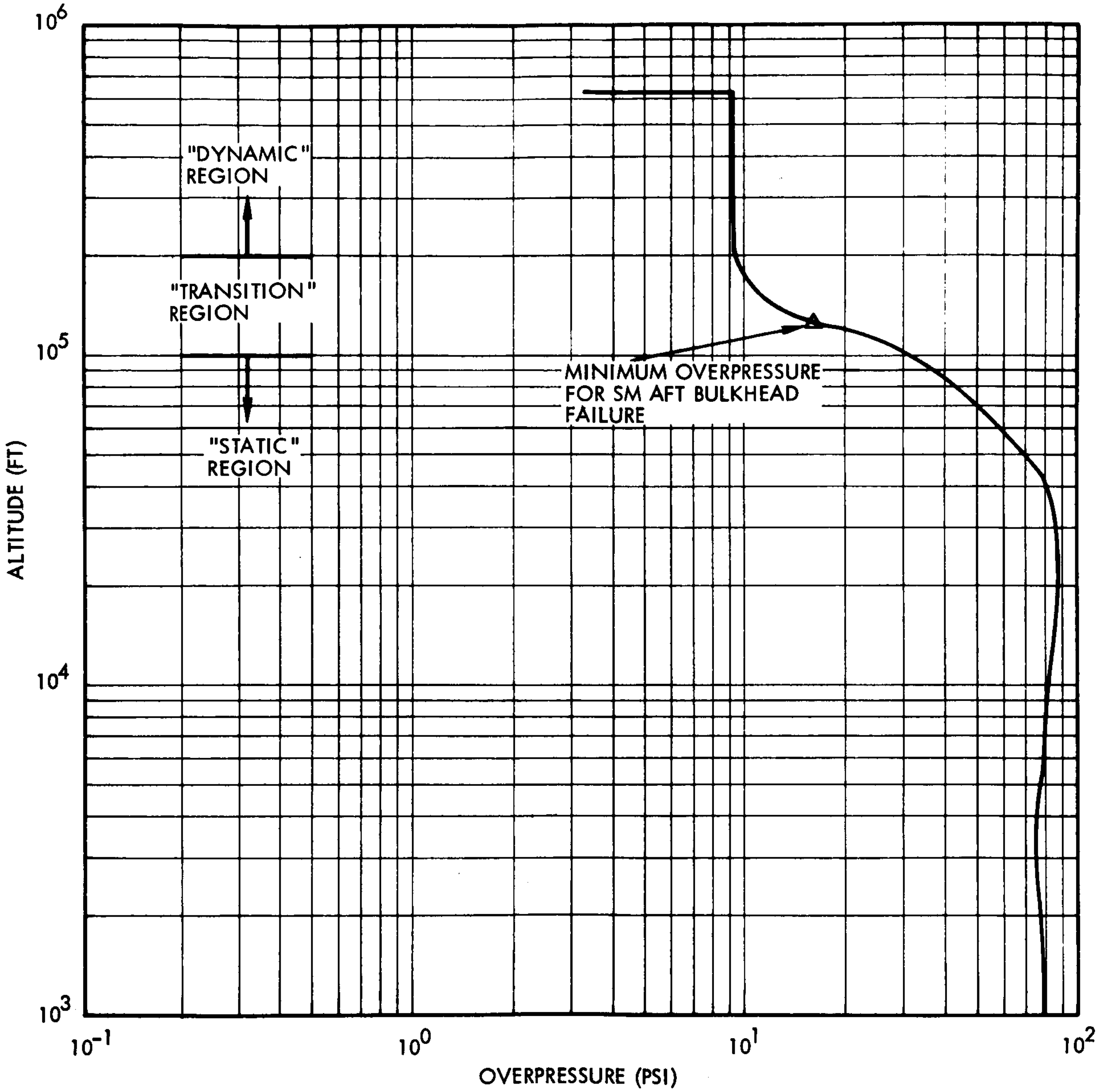

Figure 4-7. Overpressure Environment and Failure Point for SM Aft Bulkhead, Station 6

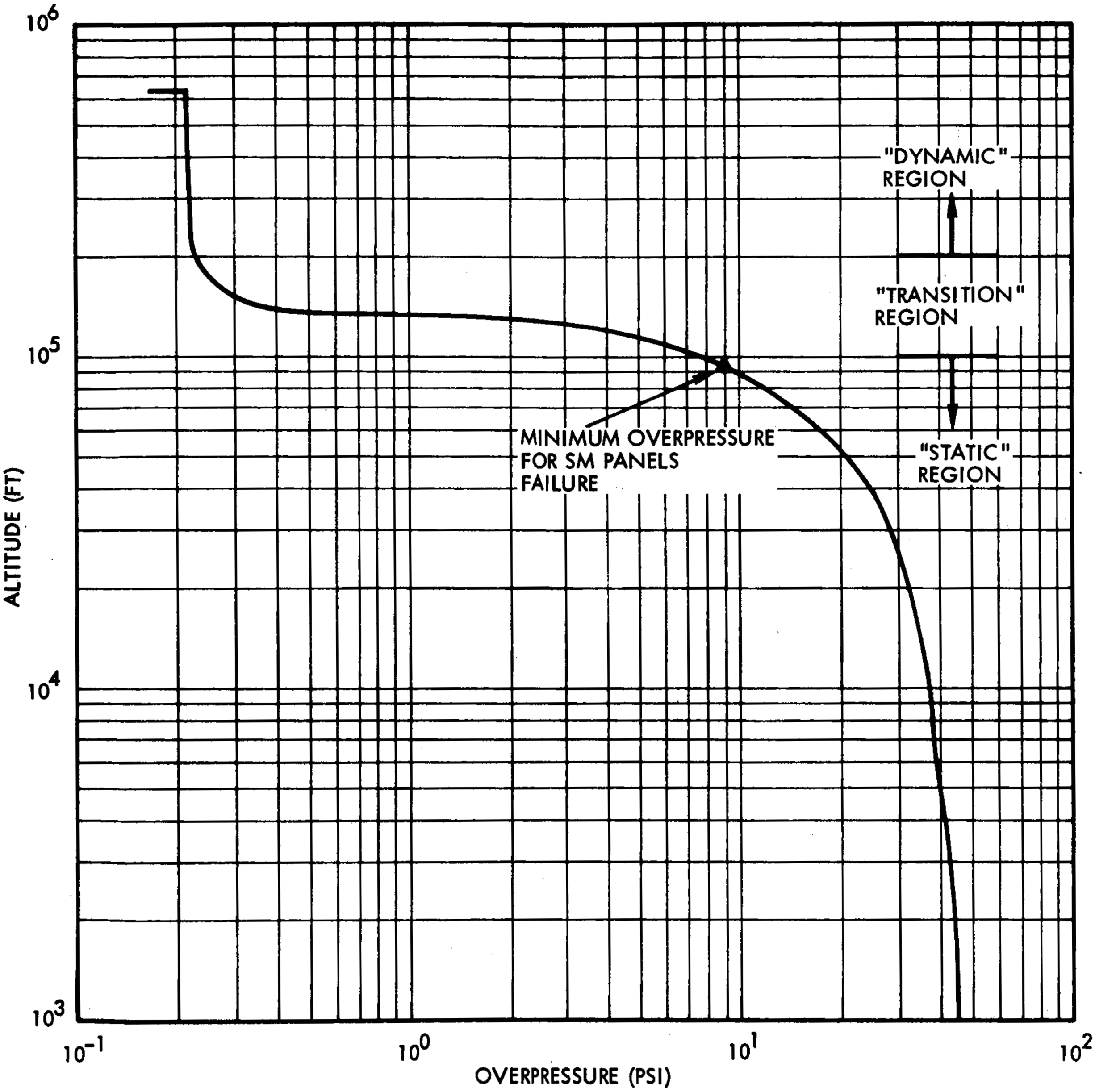

Figure 4-8. Overpressure Environment and Failure Point for SM Panels, Station 7

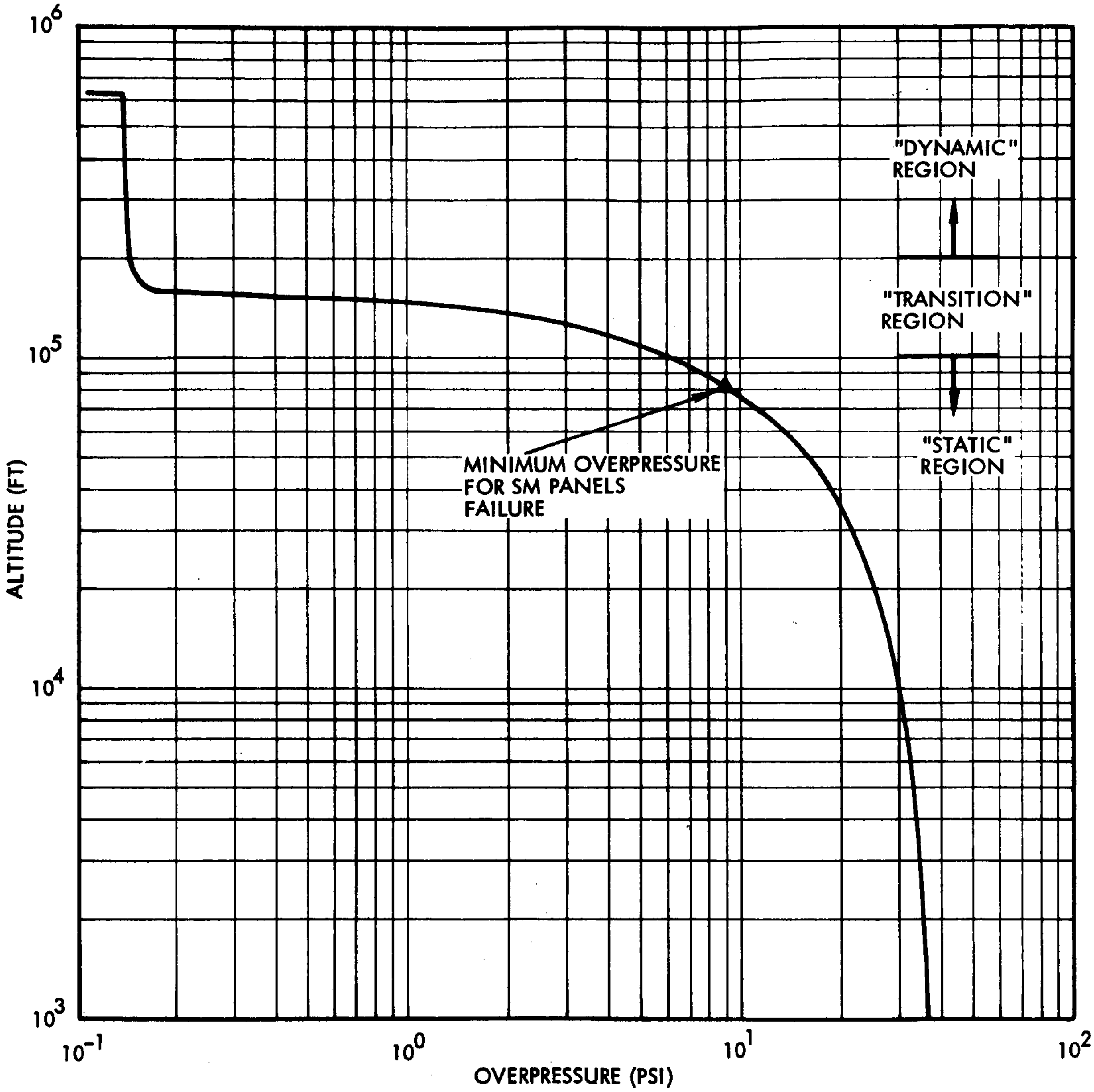

Figure 4-9. Overpressure Environment and Failure Point for SM Panels, Station 8

5. VELOCITY OF PIECES

The velocities of the spacecraft pieces relative to the spacecraft frame were determined using the impulse method found in Reference 9. The derivation of this method is shown in Reference 6. The constant impulse method for calculating the fragment initial velocities will give a conservative upper bound (i.e., the fragment velocities should not be higher).

The initial incremental velocities of the pieces for the assumed breakup modes are given in Tables 6-1 through 6-6. These velocities were calculated for structural breakups occurring during the following altitude ranges:

a) Lift-off to 95,000 feet

b) 95,000 feet to 115,000 feet

c) 115,000 feet to 125,000 feet

d) 125,000 feet to 160,000 feet

e) 160,000 feet to LES Jettison

f) LES Jettison to orbital insertion

6. LETHAL AREAS

A potential hazard to the surface of the earth will exist if any of the pieces due to breakup survive their reentry environment. There are several methods for calculating the potential lethal areas of the impacting pieces. The method employed in Reference 6 was applied herein.

Tables 6-1 through 6-6 give the lethal areas of the impacting fragments. The list below gives the altitude range for each breakup considered and the total lethal area resulting from breakup.

a) Lift-off to 95,000 feet, total lethal area - 14,680 square feet

b) 95,000 feet to 115,000 feet, total lethal area - 13,840 square feet

c) 115,000 feet to 125,000 feet, total lethal area - 13,290 square feet

d) 125,000 feet to 160,000 feet, total lethal area - 2,010 square feet

e) 160,000 feet to LES Jettison, total lethal area - 1,000 square feet

f) LES Jettison to orbital insertion, total lethal area - 2,520 square feet

Table 6-1. Results of Breakup from Lift-off to 95,000 Feet

Part	Number of Pieces	Weight/Piece (lb)	Reference Area/Piece (ft^2)	Lethal Area/Piece (ft^2)	Approximate Incremental Velocity (ft/sec)
SPS Engine	1	660.7	24.15	47.51	20
SPS Engine Nozzle	1	156.8	209.42	264.17	770
Heat Exchanger	2	8.5	9.0	25.1	530
Regulator	2	10.8	0.2	5.0	10
Oxid. Sump Tank	22	10.38	7.65	25.67	320
Oxid. Storage Tank	22	8.34	7.65	25.67	390
Fuel Sump Tank	28	8.15	5.09	15.94	270
Fuel Storage Tank	28	6.55	5.09	15.94	330
Outer Panels					
Sector I	3	24.3	23.35	45.96	400
Sector IV	3	25.83	23.35	45.36	380
Sectors II and V	2	42.99	25.00	48.27	270
Sectors II and V	4	21.49	26.79	51.93	480
Sectors III and VI	2	42.99	25.00	48.27	270
Sectors III and VI	4	21.49	22.73	45.67	410
Radial Beams	18	19.79	19.74	40.60	410
CSM Fairing					
Sectors I and IV	2	21.1	11.75	30.08	200
Sectors II and V	2	29.5	15.96	38.17	190

Table 6-1. Results of Breakup from Lift-off to 95,000 Feet (Continued)

Part	Number of Pieces	Weight/ Piece (lb)	Reference Area/ Piece (ft^2)	Lethal Area/ Piece (ft^2)	Approximate Incremental Velocity (ft/ sec)
Sectors III and VI	2	25.3	13.54	33.54	190
LOX Tank	8	9.75	1.91	6.96	80
LOX Tank	8	9.75	1.91	6.96	80
LH_2 Tank	8	8.49	2.72	8.91	160
LH_2 Tank	8	8.49	2.72	8.91	140
Fuel Cell	3	240.4	6.58	21.14	10
Check Valve	2	2.5	0.30	5.6	60
H_2 Valve Module	1	11.5	0.30	5.2	10
O_2 Valve Module	1	12.1	0.20	5.2	10
TM Package	1	27.0	0.10	4.6	10
Inst. Equipment	2	20.0	0.10	4.6	10
EPS Power Dist. Buss	1	35.3	0.10	4.6	1
CSM Umbilical Sep.	1	26.8	1.8	10.4	20
Sensors	4	12.1	0.2	7.5	10
PU Valve	1	16.5	1.1	8.4	30
He Tank	8	39.7	1.31	21.17	10
He Tank	1	318.0	13.09	29.03	15
Forward Bulkhead					
Sector I	1	13.8	16.48	36.75	430

Table 6-1. Results of Breakup from Lift-off to 95,000 Feet (Continued)

Part	Number of Pieces	Weight/ Piece (lb)	Reference Area/ Piece (ft^2)	Lethal Area/ Piece (ft^2)	Approximate Incremental Velocity (ft/ sec)
Sector II	1	20.6	23.07	47.03	400
Sector III	1	17.8	19.77	41.88	400
Sector IV	1	14.4	16.48	36.80	410
Sector V	1	20.5	23.07	47.03	400
Sector VI	1	17.8	19.77	41.88	400
Aft Bulkhead					
Sectors I and IV	2	41.6	16.48	36.79	200
Sectors II and V	2	58.4	23.07	47.03	200
Sectors III and VI	2	50.0	19.77	41.88	200
LH_2 Equip. Sup. Shelf	1	17.3	5.44	36.79	150
LOX Equip. Sup. Shelf	1	17.3	5.44	36.79	130
Fuel Cell Sup. Shelf	1	36.5	5.44	36.79	60
RCS Panels	4	34.0	16.54	36.81	190
RCS Oxid. Tank	48	1.31	0.586	4.18	170
RCS Fuel Tank	48	1.31	0.586	4.18	170
RCS He Tank	16	1.30	0.451	3.94	140
RCS Engines	16	10.3	0.1	3.6	4
RCS Mounts and Fittings	12	4.75	0.1	4.2	10

Table 6-1. Results of Breakup from Lift-off to 95,000 Feet (Continued)

Part	Number of Pieces	Weight/ Piece (lb)	Reference Area/ Piece (ft^2)	Lethal Area/ Piece (ft^2)	Approximate Incremental Velocity (ft/ sec)
Wire					
EPS	1	30.0	4.33	15.79	50
Elect. Syst.	1	20.0	4.33	15.79	80
EPS	1	17.7	4.33	15.79	90
Prop. Syst.	1	15.0	4.33	15.79	150
Prop. Syst.	1	25.0	4.33	15.79	70
Prop. Syst.	1	13.3	4.33	15.79	140
Cryo	1	30.7	4.33	15.79	60
SCS	1	28.9	4.33	15.79	50
Elect. Syst.	1	35.1	4.33	15.79	45
CSM Intr.	1	45.8	4.33	15.79	30
RCS Module	2	13.8	2.17	7.89	60
RCS Module	2	13.8	2.17	7.89	60
Hi Gain Antenna	1	76.7	28.44	53.78	190
VHF Omni Antenna	1	12.1	0.89	10.11	30
LM Ascent Engine	1	201.0	11.07	32.69	50
Fuel Tank (Ascent)	1	71.0	7.84	20.91	100
Oxid. Tank (Ascent)	1	77.9	7.84	20.91	90
He Tank (Ascent)	2	55.5	0.79	7.07	10

Table 6-1. Results of Breakup from Lift-off to 95,000 Feet (Continued)

Part	Number of Pieces	Weight/ Piece (lb)	Reference Area/ Piece (ft^2)	Lethal Area/Piece (ft^2)	Approximate Incremental Velocity (ft/sec)
GOX Tank (Ascent)	2	5.0	0.19	4.91	30
H_2O Tank (Ascent)	2	5.8	0.19	4.91	25
Battery	2	123.6	2.25	11.39	15
Inverter	2	16.9	0.63	7.61	30
Relay Box	1	4.5	0.17	4.97	30
Lighting Control	1	7.0	0.42	6.22	60
ECS Relay Box	1	2.5	0.39	6.03	120
Elect. Control Assy	2	10.3	0.34	5.82	25
Auxil. SW Relay Box	1	3.5	0.53	6.68	150
Wire					
S and C	1	16.2	4.33	15.79	220
NSG	1	97.0	4.33	15.79	40
Crew Provisions	1	2.5	4.33	15.79	1330
ECS	1	4.1	4.33	15.79	840
Instrument	1	171.0	4.33	15.79	20
EPS	1	13.2	4.33	15.79	270
EED	1	2.7	4.33	15.79	1240
Propulsion	1	19.0	4.33	15.79	190
RCS	1	14.3	4.33	15.79	250

Table 6-1. Results of Breakup from Lift-off to 95,000 Feet (Continued)

Part	Number of Pieces	Weight/ Piece (lb)	Reference Area/ Piece (ft^2)	Lethal Area/ Piece (ft^2)	Approximate Incremental Velocity (ft/sec)
Communications	1	7.9	4.33	15.79	450
Sig. Processor Assy	1	9.4	0.29	5.59	30
AS Coaxial Assy	1	18.0	4.33	15.79	200
S-Band Transceiver	1	19.8	0.77	7.73	30
Power Amplifier	1	15.7	0.68	7.32	35
DEDA Data Entry	1	7.8	0.25	4.77	30
DSKY Data Stor. Key	1	17.5	0.69	7.15	30
Heat Exchanger	1	14.2	1.35	9.26	80
RCS Fuel Tank	2	9.2	3.00	14.14	255
RCS Oxid. Tank	2	10.9	3.00	14.14	220
RCS He Tank	2	8.2	0.79	7.07	80
RCS Engines	16	5.04	0.10	4.42	20
RCS Nozzles	16	4.75	0.25	5.89	45
ATCA	1	23.6	1.01	8.49	35
Abort Sensors	1	20.7	0.75	7.39	30
Abort Electrode	1	32.5	0.78	7.61	20
PCMTEA	1	23.0	1.79	11.61	70
IMU Platform	1	42.4	1.51	10.82	25
AOT Telescope	1	22.5	0.96	14.67	30

Table 6-1. Results of Breakup from Lift-off to 95,000 Feet (Continued)

Part	Number of Pieces	Weight/ Piece (lb)	Reference Area/ Piece (ft^2)	Lethal Area/Piece (ft^2)	Approximate Incremental Velocity (ft/sec)
Navigation Base	1	3.9	0.16	6.97	35
CDU Converter	1	37.0	1.61	10.93	40
PLSS	1	65.8	3.34	14.82	40
PLSS	1	65.8	3.34	14.82	40
Harness "A"	1	22.0	0.63	14.86	20
LGC Computer	1	65.0	2.09	12.21	25
PSA Servo and SCA	1	28.2	1.42	10.73	45
PTA Torquer	1	14.3	1.05	9.17	55
LM Descent Engine	1	406.8	25.56	59.63	75
Oxid. Tank (Descent)	2	121.9	22.31	45.45	210
Fuel Tank (Descent)	2	110.2	22.31	45.45	240
GOX Tank (Descent)	1	59.0	0.79	7.07	25
He Tank (Descent)	1	98.2	4.30	14.79	50
H_2O Tank (Descent)	1	22.1	6.37	20.48	320
Battery	2	137.1	2.09	12.81	20
Pryo. Battery	2	3.5	0.39	6.03	110
EED Relay Box	2	6.0	0.11	4.57	20
Elect. Control Assy	2	20.2	0.25	5.39	15

Table 6-1. Results of Breakup from Lift-off to 95,000 Feet (Continued)

Part	Number of Pieces	Weight/ Piece (lb)	Reference Area/ Piece (ft^2)	Lethal Area/ Piece (ft^2)	Approximate Incremental Velocity (ft/sec)
Wire					
N and G	1	2.4	1.12	8.94	520
EPS	1	7.0	1.67	10.15	245
EED	1	2.6	1.67	10.15	630
Propulsion	1	4.2	1.67	10.15	440
Instruments	1	26.2	4.33	12.81	190
GBL Driver Actuator	2	3.5	0.25	5.55	80
PQGS Control Unit	1	3.1	0.21	5.39	90
LR Antenna Assy	1	26.0	0.48	7.32	10
DECA	1	8.2	0.25	5.39	30
Battery	2	137.1	2.09	12.81	20
Structural Skin	48	14.47	1.56	9.70	120
Structural Skin	32	14.14	1.37	9.19	110
Structural Skin	40	12.26	0.76	7.41	50
Outrigger Structure	4	33.28	5.83	27.24	240
Outer Skin (Ascent)	120	0.002	3.00	7.50	730
Outer Skin (Descent)	64	0.0025	4.00	16.00	780
Landing Gear	4	115.3	4.63	29.75	60

Table 6-1. Results of Breakup from Lift-off to 95,000 Feet (Continued)

Part	Number of Pieces	Weight/ Piece (lb)	Reference Area/ Piece (ft^2)	Lethal Area/Piece (ft^2)	Approximate Incremental Velocity (ft/sec)
SLA Upper Panels					
Panel 1	1	182.24	186.68	251.35	590
Panel 1	1	274.36	295.08	376.02	860
Panels 2 and 3	2	178.4	186.68	251.35	600
Panels 2 and 3	2	267.6	295.08	376.02	880
Panel 4	1	171.84	186.68	251.35	620
Panel 4	1	257.76	295.08	376.02	910
SLA Lower Panels	4	253.5	222.2	304.18	1000
RTG Fuel Cask	1	43.57	1.22	10.22	35
ALSEP Compartment No. 1					
Magnetometer	1	14.5	1.99	12.08	165
Passive Seismic	1	25.0	1.14	9.43	55
Solar Wind	1	10.0	1.07	9.48	130
Structural/Thermal	1	63.68	4.25	16.52	80
ALSEP Compartment No. 2					
Power Generation Assy	1	25.45	2.16	12.05	100
Structural/Thermal	1	11.85	4.25	16.52	420
Lunar Hand Tools and Carrier	1	27.27	3.39	14.86	150

Table 6-1. Results of Breakup from Lift-off to 95,000 Feet (Continued)

Part	Number of Pieces	Weight/Piece (lb)	Reference Area/Piece (ft^2)	Lethal Area/Piece (ft^2)	Approximate Incremental Velocity (ft/sec)
Suprathermal Ion Detector	1	16.70	0.97	9.05	70
Passive Seismic Base	1	0.12	1.00	9.00	5870
S-Band Erectable Ant.	1	17.8	2.78	15.11	190
TOTAL	832			14,681.45	

Table 6-2. Results of Breakup from 95, 000 Feet to 115, 000 Feet

Part	Number of Pieces	Weight/ Piece (lb)	Reference Area/ Piece (ft^2)	Lethal Area/Piece (ft^2)	Approximate Incremental Velocity (ft/sec)
SPS Engine	1	660. 7	24. 15	47. 51	20
SPS Engine Nozzle	1	156. 8	209. 42	264. 17	770
Heat Exchanger	2	8. 5	9. 0	25. 1	530
Regulator	2	10. 8	0. 2	5. 0	10
Oxid. Sump Tank	22	10. 38	7. 65	25. 67	320
Oxid. Storage Tank	22	8. 34	7. 65	25. 67	390
Fuel Sump Tank	28	8. 15	5. 09	15. 94	270
Fuel Storage Tank	28	6. 55	5. 09	15. 94	330
Outer Panels					
Sector I	3	24. 3	23. 35	45. 96	400
Sector IV	3	25. 83	23. 35	45. 36	380
Sectors II and V	2	42. 99	25. 00	48. 27	270
Sectors II and V	4	21. 49	26. 79	51. 93	480
Sectors III and VI	2	42. 99	25. 00	48. 27	270
Sectors III and VI	4	21. 49	22. 73	45. 67	410
Radial Beams	18	19. 79	19. 74	40. 60	410
CSM Fairing					
Sectors I and IV	2	21. 1	11. 75	30. 08	200
Sectors II and V	2	29. 5	15. 96	38. 17	190

Table 6-2. Results of Breakup from 95,000 Feet to 115,000 Feet (Continued)

Part	Number of Pieces	Weight/Piece (lb)	Reference Area/Piece (ft^2)	Lethal Area/Piece (ft^2)	Approximate Incremental Velocity (ft/sec)
Sectors III and VI	2	25.3	13.54	33.54	190
LOX Tank	8	9.75	1.91	6.96	80
LOX Tank	8	9.75	1.91	6.96	80
LH_2 Tank	8	8.49	2.72	8.91	160
LH_2 Tank	8	8.49	2.72	8.91	140
Fuel Cell	3	240.4	6.58	21.14	10
Check Valve	2	2.5	0.30	5.6	60
H_2 Valve Module	1	11.5	0.30	5.2	10
O_2 Valve Module	1	12.1	0.20	5.2	10
TM Package	1	27.0	0.10	4.6	10
Inst. Equipment	2	20.0	0.10	4.6	1
EPS Power Dist. Buss	1	35.3	0.10	4.6	1
CSM Umbilical Sep.	1	26.8	1.8	10.4	20
Sensors	4	12.1	0.2	7.5	10
PU Valve	1	16.5	1.1	8.4	30
He Tank	8	39.7	1.31	21.17	10
He Tank	1	318.	13.09	29.03	15
Forward Bulkhead					
Sector I	1	13.8	16.48	36.75	430

Table 6-2. Results of Breakup from 95,000 Feet to 115,000 Feet (Continued)

Part	Number of Pieces	Weight/ Piece (lb)	Reference Area/ Piece (ft^2)	Lethal Area/Piece (ft^2)	Approximate Incremental Velocity (ft/sec)
Sector II	1	20.06	23.07	47.03	400
Sector III	1	17.8	19.77	41.88	400
Sector IV	1	14.4	16.48	36.80	410
Sector V	1	20.5	23.07	47.03	400
Sector VI	1	17.8	19.77	41.88	400
AFT Bulkhead					
Sector I and IV	2	41.6	16.48	36.79	200
Sector II and V	2	58.4	23.07	47.03	200
Sector III and VI	2	50.0	19.77	41.88	200
LH_2 Equip. Sup. Shelf	1	17.3	5.44	36.79	150
LOX Equip. Sup. Shelf	1	17.3	5.44	36.79	130
Fuel Cell Sup. Shelf	1	36.5	5.44	36.79	60
RCS Panels	4	34.0	16.54	36.81	190
RCS Oxid. Tank	48	1.31	0.586	4.18	170
RCS Fuel Tank	48	1.31	0.586	4.18	170
RCS He Tank	16	1.30	0.451	3.94	140
RCS Engines	16	10.3	0.1	3.6	4
RCS Mounts and Fittings	12	4.75	0.1	4.2	10

Table 6-2. Results of Breakup from 95,000 Feet to 115,000 Feet (Continued)

Part	Number of Pieces	Weight/ Piece (lb)	Reference Area/ Piece (ft^2)	Lethal Area/Piece (ft^2)	Approximate Incremental Velocity (ft/sec)
Wire					
EPS	1	30.0	4.33	15.79	50
Elect. Syst.	1	20.0	4.33	15.79	80
EPS	1	17.7	4.33	15.79	90
Prop. Syst.	1	15.0	4.33	15.79	150
Prop. Syst.	1	25.0	4.33	15.79	70
Prop. Syst.	1	13.3	4.33	15.79	140
CRYO	1	30.7	4.33	15.79	60
SCS	1	28.9	4.33	15.79	50
Elect. Syst.	1	35.1	4.33	15.79	45
CSM Intr.	1	45.8	4.33	15.79	30
RCS Module	2	13.8	2.17	7.89	60
RCS Module	2	13.8	2.17	7.89	60
Hi Gain Antenna	1	76.7	28.44	53.78	190
VHF Omni Antenna	1	12.1	.89	10.11	30
Fuel Tank (Ascent)	1	71.0	7.84	20.91	100
Oxid Tank (Ascent)	1	77.9	7.84	20.91	90

Table 6-2. Results of Breakup from 95,000 Feet to 115,000 Feet (Continued)

Part	Number of Pieces	Weight/ Piece (lb)	Reference Area/ Piece (ft^2)	Lethal Area/Piece (ft^2)	Approximate Incremental Velocity (ft/sec)
He Tank (Ascent)	2	55.5	0.79	7.07	10
Gox Tank (Ascent)	2	5.0	0.19	4.91	30
H_2O Tank (Ascent)	2	5.8	0.19	4.91	25
Battery	2	123.6	2.25	11.39	15
Inverter	2	16.9	0.63	7.61	30
Heat Exchanger	1	14.2	1.35	9.26	80
RCS Fuel Tank	2	9.2	3.00	14.14	255
RCS Oxid Tank	2	10.9	3.00	14.14	220
RCS He Tank	2	8.2	0.79	7.07	80
RCS Engines	16	5.04	0.10	4.42	20
RCS Nozzles	16	4.75	0.25	5.89	45
Oxid. Tank (Descent)	2	121.9	22.31	45.45	210
Fuel Tank (Descent	2	110.2	22.31	45.45	240
Gox Tank (Descent)	1	59.0	0.79	7.07	25
He Tank (Descent)	1	98.2	4.30	14.79	50
H_2O Tank (Descent)	1	22.1	6.37	20.48	320
Battery	2	137.1	2.09	12.81	20
Pryo Battery	2	3.5	0.39	6.03	110

Table 6-2. Results of Breakup from 95,000 Feet to 115,000 Feet (Continued)

Part	Number of Pieces	Weight/ Piece (lb)	Reference Area/ Piece (ft^2)	Lethal Area/Piece (ft^2)	Approximate Incremental Velocity (ft/sec)
EED Relay Box	2	6.0	0.11	4.57	20
Elect. Control Assy	2	20.2	0.25	5.39	15
LM Descent Engine	1	406.8	25.56	59.63	75
Wire N and G	1	2.4	1.12	8.94	520
EPS	1	7.0	1.67	10.15	245
EED	1	2.6	1.67	10.15	630
Propulsion	1	4.2	1.67	10.15	440
Instruments	1	26.2	4.33	12.81	190
GBL Driver Actuator	2	3.5	0.25	5.55	80
PQGS Control Unit	1	3.1	0.21	5.39	90
LR Antenna Assy	1	26.0	0.48	7.32	10
DECA	1	8.2	0.25	5.39	30
Battery	2	137.1	2.09	12.81	20
Structural Skin	48	14.47	1.56	9.70	120
Outrigger Structure	4	33.28	5.83	27.24	240
Outer Skin (Ascent)	120	0.002	3.00	7.50	730
Outer Skin (Descent)	64	0.0025	4.00	16.00	780
Landing Gear	4	115.3	4.63	29.75	60

Table 6-2. Results of Breakup from 95, 000 Feet to 115, 000 Feet (Continued)

Part	Number of Pieces	Weight/ Piece (lb)	Reference Area/ Piece (ft^2)	Lethal Area/Piece (ft^2)	Approximate Incremental Velocity (ft/sec)
SLA Upper Panels					
Panel 1	1	182. 24	186. 68	251. 35	590
Panel 1	1	274. 36	295. 08	376. 02	860
Panel 2 and 3	2	178. 4	186. 68	251. 35	600
Panel 2 and 3	2	267. 6	295. 08	376. 02	880
Panel 4	1	171. 84	186. 68	251. 35	620
Panel 4	1	257. 76	295. 08	376. 02	910
SLA Lower Panels	4	253. 5	222. 2	304. 18	1000
Midsection and Crew					
Section Plus Components	1	4631. 3	127. 30	177. 10	Negligible
RTG Fuel Cask	1	43. 57	1. 22	10. 22	35
ALSEP Compartment No. 1					
Magnetometer	1	14. 5	1. 99	12. 08	165
Passive Seismic	1	25. 0	1. 14	9. 43	55
Solar Wind	1	10. 0	1. 07	9. 48	130
Structural/Thermal	1	63. 68	4. 25	16. 52	80

Table 6-2. Results of Breakup from 95,000 Feet to 115,000 Feet (Continued)

Part	Number of Pieces	Weight/ Piece (lb)	Reference Area/ Piece (ft^2)	Lethal Area/Piece (ft^2)	Approximate Incremental Velocity (ft/sec)
Alsep Compartment No. 2					
Power Generation Assy.	1	25.45	2.16	12.05	100
Structural/Thermal	1	11.85	4.25	16.52	420
Lunar Hand Tools and Carrier	1	27.27	3.39	14.86	150
Suprathermal Ion Detector	1	16.70	0.97	9.05	70
Passive Seismic Base	1	0.12	1.00	9.00	5870
S-Band Erectable Ant.	1	17.8	2.78	15.11	190
TOTAL	726			13,838.49	

Table 6-3. Results of Breakup from 115,000 Feet to 125,000 Feet

Part	Number of Pieces	Weight/ Piece (lb)	Reference Area/ Piece (ft^2)	Lethal Area/Piece (ft^2)	Approximate Incremental Velocity (ft/sec)
SPS Engine	1	660.7	24.15	47.51	20
SPS Engine Nozzle	1	156.8	209.42	264.17	770
Heat Exchanger	2	8.5	9.0	25.1	530
Regulator	2	10.8	0.2	5.0	10
Oxid. Sump Tank	22	10.38	7.65	25.67	320
Oxid. Storage Tank	22	8.34	7.65	25.67	390
Fuel Sump Tank	28	8.15	5.09	15.94	270
Fuel Storage Tank	28	6.55	5.09	15.94	330
Outer Panels					
Sector I	3	24.3	23.35	45.96	400
Sector IV	3	25.83	23.35	45.36	380
Sectors II and V	2	42.99	25.00	48.27	270
Sectors II and V	4	21.49	26.79	51.93	480
Sectors III and VI	2	42.99	25.00	48.27	270
Sectors III and VI	4	21.49	22.73	45.67	410
Radial Beams	18	19.79	19.74	40.60	410
CSM Fairing					
Sectors I and IV	2	21.1	11.75	30.08	200
Sectors II and V	2	29.5	15.96	38.17	190

Table 6-3. Results of Breakup from 115,000 Feet to 125,000 Feet (Continued)

Part	Number of Pieces	Weight/Piece (lb)	Reference Area/Piece (ft^2)	Lethal Area/Piece (ft^2)	Approximate Incremental Velocity (ft/sec)
Sectors III and VI	2	25.3	12.54	33.54	190
LOX Tank	8	9.75	1.91	6.96	80
LOX Tank	8	9.75	1.91	6.96	80
LH_2 Tank	8	8.49	2.72	8.91	160
LH_2 Tank	8	8.49	2.72	8.91	140
Fuel Cell	3	240.4	6.58	21.14	10
Check Valve	2	2.5	0.30	5.6	60
H_2 Valve Module	1	11.5	0.30	5.2	10
O_2 Valve Module	1	12.1	0.20	5.2	10
TM Package	1	27.0	0.10	4.6	10
Inst. Equipment	2	20.0	0.10	4.6	1
EPS Power Dist. Buss	1	35.3	0.10	4.6	1
CSM Umbilical Sep.	1	26.8	1.8	10.4	20
Sensors	4	12.1	0.2	7.5	10
PU Valve	1	16.5	1.1	8.4	30
He Tank	8	39.7	1.31	21.17	10
He Tank	1	318.	13.09	29.03	15
Forward Bulkhead Sector I	1	13.8	16.48	36.75	430

Table 6-3. Results of Breakup from 115,000 Feet to 125,000 Feet (Continued)

Part	Number of Pieces	Weight/Piece (lb)	Reference Area/Piece (ft^2)	Lethal Area/Piece (ft^2)	Approximate Incremental Velocity (ft/sec)
Sector II	1	20.06	23.07	47.03	400
Sector III	1	17.8	19.77	41.88	400
Sector IV	1	14.4	16.48	36.80	410
Sector V	1	20.5	23.07	47.03	400
Sector VI	1	17.8	19.77	41.88	400
AFT Bulkhead					
Sector I and IV	2	41.6	16.48	36.79	200
Sector II and V	2	58.4	23.07	47.03	200
Sector III and VI	2	50.0	19.77	41.88	200
LH_2 Equip. Sup. Shelf	1	17.3	5.44	36.79	150
LOX Equip. Sup. Shelf	1	17.3	5.44	36.79	130
Fuel Cell Sup. Shelf	1	36.5	5.44	36.79	60
RCS Panels	4	34.0	16.54	36.81	190
RCS Oxid. Tank	48	1.31	0.586	4.18	170
RCS Fuel Tank	48	1.31	0.586	4.18	170
RCS He Tank	16	1.30	0.451	3.94	140
RCS Engines	16	10.3	0.1	3.6	4
RCS Mounts and Fittings	12	4.75	0.1	4.2	10

Table 6-3. Results of Breakup from 115, 000 Feet to 125, 000 Feet (Continued)

Part	Number of Pieces	Weight/ Piece (lb)	Reference Area/ Piece (ft^2)	Lethal Area/Piece (ft^2)	Approximate Incremental Velocity (ft/sec)
Wire					
EPS	1	30. 0	4. 33	15, 79	50
Elect. Syst.	1	20. 0	4. 33	15. 79	80
EPS	1	17. 7	4. 33	15. 79	90
Prop. Syst.	1	15. 0	4. 33	15. 79	150
Prop. Syst.	1	25. 0	4. 33	15. 79	70
Prop. Syst.	1	13. 3	4. 33	15. 79	140
CRYO	1	30. 7	4. 33	15. 79	60
SCS	1	28. 9	4. 33	15. 79	50
Elect. Syst.	1	35. 1	4. 33	15. 79	45
CSM Intr.	1	45. 8	4. 33	15. 79	30
RCS Module	2	13. 8	2. 17	7. 89	60
RCS Module	2	13. 8	2. 17	7. 89	60
Hi Gain Antenna	1	76. 7	28. 44	53. 78	190
VHF Omni Antenna	1	12. 1	. 89	10. 11	30
Fuel Tank (Ascent)	1	71. 0	7. 84	20. 91	100
Oxid Tank (Ascent)	1	77. 9	7. 84	20. 91	90

Table 6-3. Results of Breakup from 115,000 Feet to 125,000 Feet (Continued)

Part	Number of Pieces	Weight/Piece (lb)	Reference Area/Piece (ft^2)	Lethal Area/Piece (ft^2)	Approximate Incremental Velocity (ft/sec)
He Tank (Ascent)	2	55.5	0.79	7.07	10
GOX Tank (Ascent)	2	5.0	0.19	4.91	30
H_2O Tank (Ascent)	2	5.8	0.19	4.91	25
Battery	2	123.6	2.25	11.39	15
Inverter	2	16.9	0.63	7.61	30
Heat Exchanger	1	14.2	1.35	9.26	80
RCS Fuel Tank	2	9.2	3.00	14.14	255
RCS Oxid Tank	2	10.9	3.00	14.14	220
RCS HE Tank	2	8.2	0.79	7.07	80
RCS Engines	16	5.04	0.10	4.42	20
RCS Nozzles	16	4.75	0.25	5.89	45
GOX Tank (Descent)	1	59.0	0.79	7.07	25
He Tank (Descent)	1	98.2	4.30	14.79	50
H_2O Tank (Descent)	1	22.1	6.37	20.48	320
Battery	2	137.1	2.09	12.81	20
Pryo Battery	2	3.5	0.39	6.03	110
LR Antenna Assy	1	26.0	0.48	7.32	10
Battery	2	137.1	2.09	12.81	20

Table 6-3. Results of Breakup from 115, 000 to 125, 000 Feet (Continued)

Part	Number of Pieces	Weight/ Piece (lb)	Reference Area/ Piece (ft^2)	Lethal Area/Piece (ft^2)	Approximate Incremental Velocity (ft/sec)
Outer Skin (Ascent)	120	0. 002	3. 00	7. 50	730
Outer Skin (Descent)	64	0. 0025	4. 00	16. 00	780
Landing Gears	4	115. 3	4. 63	29. 75	60
SLA Upper Panels					
Panel 1	1	182. 24	186. 68	251. 35	590
Panel 1	1	274. 36	295. 08	376. 02	860
Panels 2 and 3	2	178. 4	186. 68	251. 35	600
Panels 2 and 3	2	267. 6	295. 08	376. 02	880
Panel 4	1	171. 84	186. 68	251. 35	620
Panel 4	1	257. 76	295. 08	376. 02	910
SLA Lower Panels	4	253. 5	222. 2	304. 18	1000
Midsection and Crew					
Section Plus Components	1	4631. 3	127. 30	177. 10	Negligible
Descent Inner Structure					
Plus Components	1	4787. 7	368. 56	439. 74	Negligible
ALSEP Compartment No. 1	1	114. 56	4. 25	16. 52	45

Table 6-3. Results of Breakup from 115, 000 to 125, 000 Feet (Continued)

Part	Number of Pieces	Weight/ Piece (lb)	Reference Area/ Piece (ft^2)	Lethal Area/Piece (ft^2)	Approximate Incremental Velocity (ft/sec)
ALSEP Compartment No. 2	1	85.03	4.25	16.52	60
RTG Fuel Cask	1	43.57	1.22	10.22	35
S-Band Erectable Ant.	1	17.8	2.78	15.11	190
TOTAL	647			13,292.86	

Table 6-4. Results of Breakup from 125, 000 Feet to 160, 000 Feet

Part	No. of Pieces	Weight/ Piece (lb)	Reference Area/Piece (ft^2)	Lethal Area/Piece (ft^2)	Approximately Incremental Velocity (ft/sec)
SM, LM, and SLA	1	66394. 7	779. 92	999. 92	Negligible
Outer Skin (Descent)	64	0. 0025	4. 0	16. 0	Negligible
TOTAL	65			2, 013. 92	

Table 6-5. Results of Breakup from 160, 000 Feet to LES Jettison

Part	No. of Pieces	Weight/ Piece (lb)	Reference Area/Piece (ft^2)	Lethal Area/Piece (ft^2)	Approximately Incremental Velocity (ft/sec)
SM, LM, and SLA	1	66, 394. 7	779. 92	999. 92	Negligible
TOTAL	1			999. 92	

Table 6-6. Results of Breakup from LES Jettison to Orbital Insertion

Part	No. of Pieces	Weight/ Piece (lb)	Reference Area/Piece (ft^2)	Lethal Area/Piece (ft^2)	Approximately Incremental Velocity (ft/sec)
SLA Upper Panels	4	640.0	428.69	519.44	Negligible
LM and SLA Lower Panels	1	29,397.5	368.56	439.74	Negligible
TOTAL	5			2,517.5	

APPENDIX A

SPACECRAFT CONFIGURATION FOR MISSION AS-504

APPENDIX A

SPACECRAFT CONFIGURATION FOR MISSION AS-504

1. CONFIGURATION

1.1 Service Module

The Service Module is designed to contain the systems and equipment necessary to support the Command Module and SPS engine. The SM used for this mission is of the Block II type. Reference 10 provides a more complete description of the SM, which is shown in Figures A-1 and A-2.

1.2 Lunar Module

The Lunar Module is designed to contain the systems and equipment necessary to land, support, and return two astronauts from the lunar surface to the orbiting Command and Service Modules. Reference 1 provides a more complete description of the LM, which is shown in Figure A-3.

1.3 Spacecraft LM Adapter

The Spacecraft LM Adapter is designed to house the LM from lift-off to translunar injection. A more complete description of the SLA is contained in Reference 6, it is also illustrated in Figure A-4.

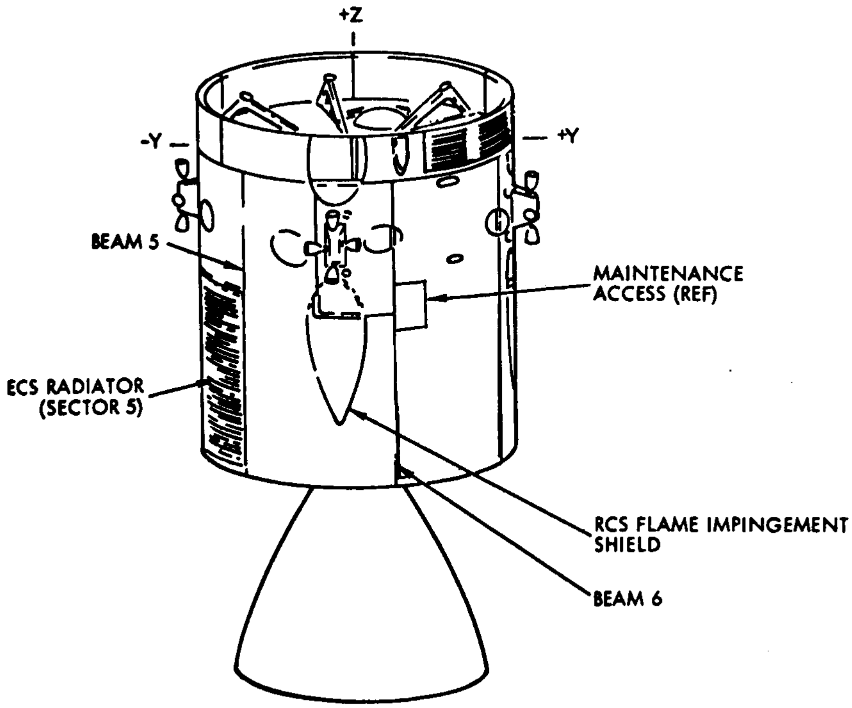

Figure A-1. Service Module Outboard Configuration

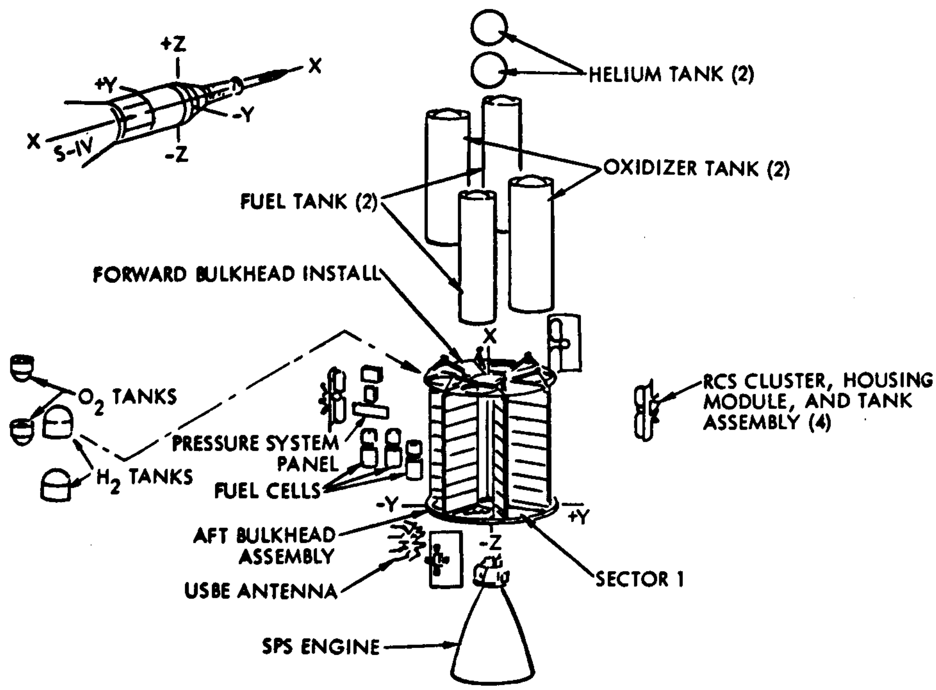

Figure A-2. Service Module Structure and Systems Equipment

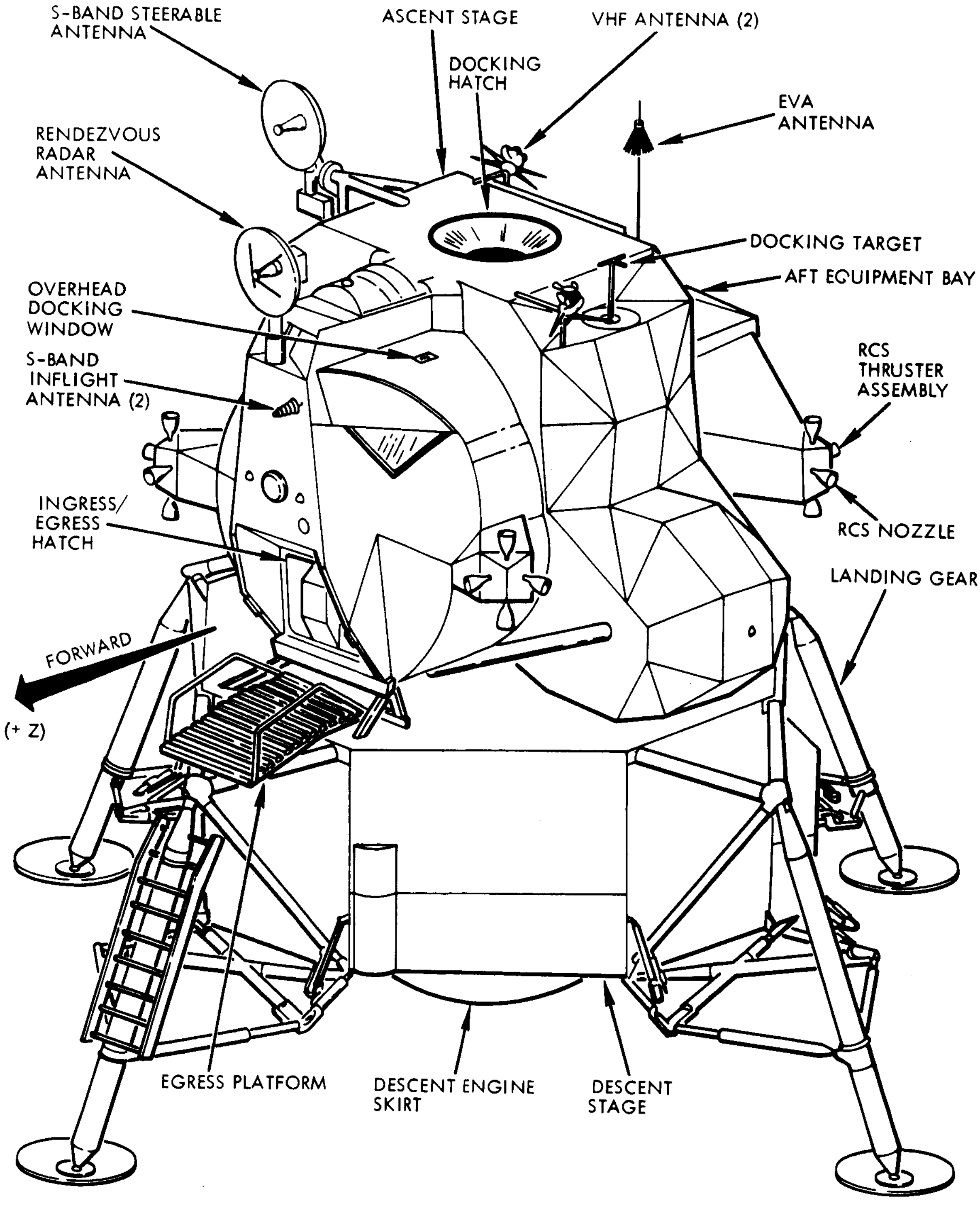

Figure A-3. Lunar Module

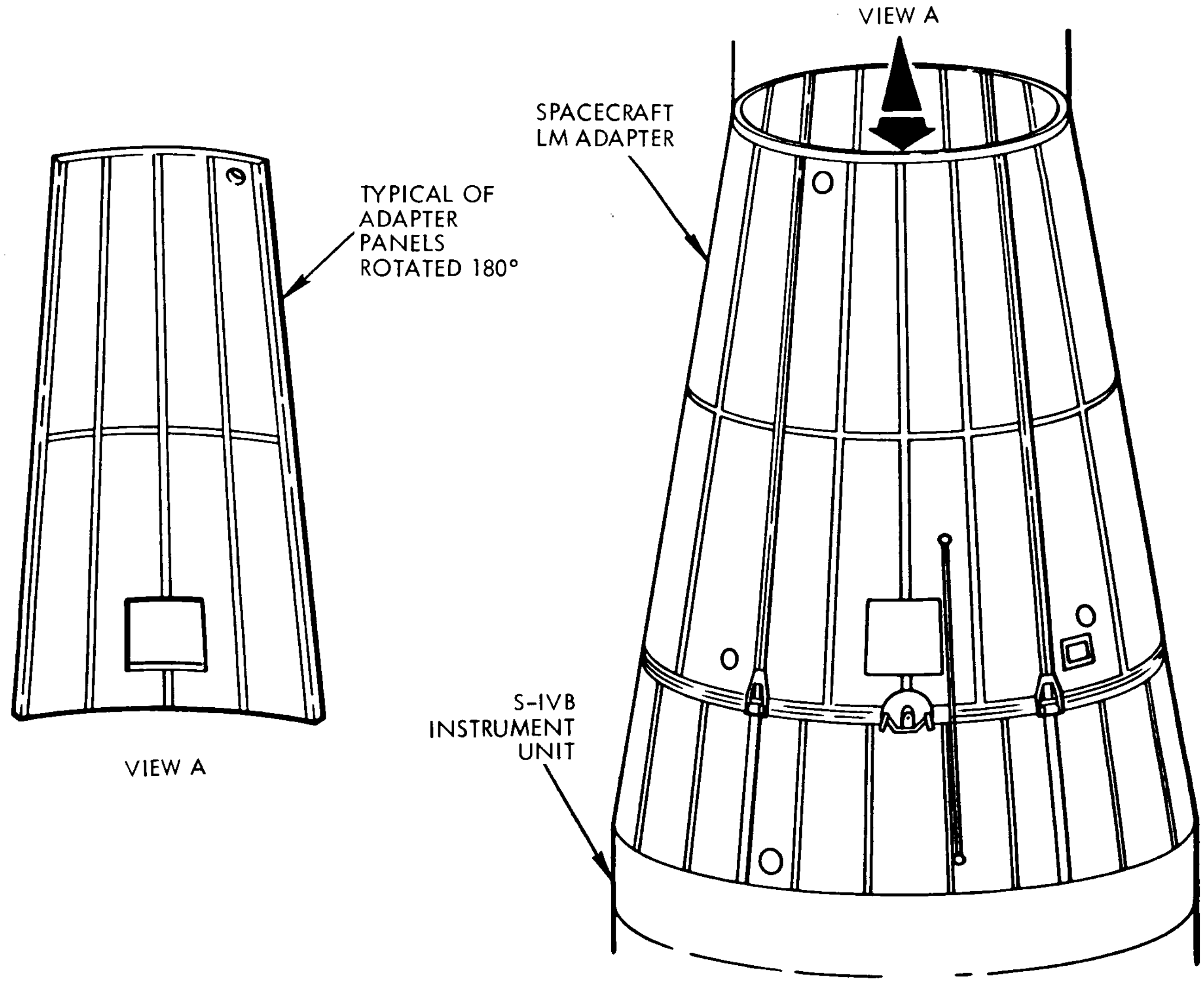

Figure A-4. Spacecraft LM Adapter

APPENDIX B

STRUCTURAL CAPABILITY OF SPACECRAFT ELEMENTS

APPENDIX B

STRUCTURAL CAPABILITY OF SPACECRAFT ELEMENTS

1. INTRODUCTION

The overpressure realized by the spacecraft structural components are caused by an explosion; therefore, the stresses realized will be the results of impulse or impact loading. Reference 11 states that sudden loading will generally cause approximately twice as much stress and deflection as static loading. The failure stresses were calculated for static loading and then reduced by a factor of 2 to account for the pressure impulse loading. Structural degradation as a result of aerodynamic heating and the thermal pulse caused by the exploding propellants was not considered in this analysis. Such structural degradation will have a negligible effect on the number of pieces, fragment size, and incremental velocities resulting from destruct action.

2. SERVICE MODULE

The upper bound failure overpressure for the SM outer panels was calculated to be 9 psi (Reference 6). The SM aft bulkhead upper bound failure overpressure was calculated to be 16 psi (Reference 6).

3. SPACECRAFT LM ADAPTER

The upper bound failure overpressure for the SLA panels was calculated to be 8.5 psi (Reference 10).

4. LUNAR MODULE

4.1 LM Ascent Stage

The LM ascent stage outer skin was idealized as a series of different sized rectangular panels shown in Figure B-1. The failure overpressures for these idealized panels (A through G and J) were calculated to range from approximately 2 psi to 10 psi using the method outlined in Reference 6. The crew hatch (H) failure overpressure was found to be 380 psi due to its construction of much thicker material.

The inner structure was idealized as shown in Figure B-2 and was analyzed in a like manner as the outer skin. The failure overpressures for panels 1 through 9 were calculated to range from 15 psi to 75 psi. The aft midsection bulkhead was found to have a failure overpressure of approximately 76 psi (Reference 1).

4.2 LM Descent Stage

The descent stage outer skin was idealized into panels in the same manner as the ascent stage, and is shown in Figure B-1. The calculated range of failure overpressures was found to be 1.3 psi to 1.5 psi.

The inner structure was again idealized and analyzed as the ascent stage, and is shown in Figure B-3. The side panels (1, 2, and 3) were found to have a failure overpressure range of 10 psi to 50 psi. The lower deck panels (4) were found to fail at any overpressure of approximately 215 psi.

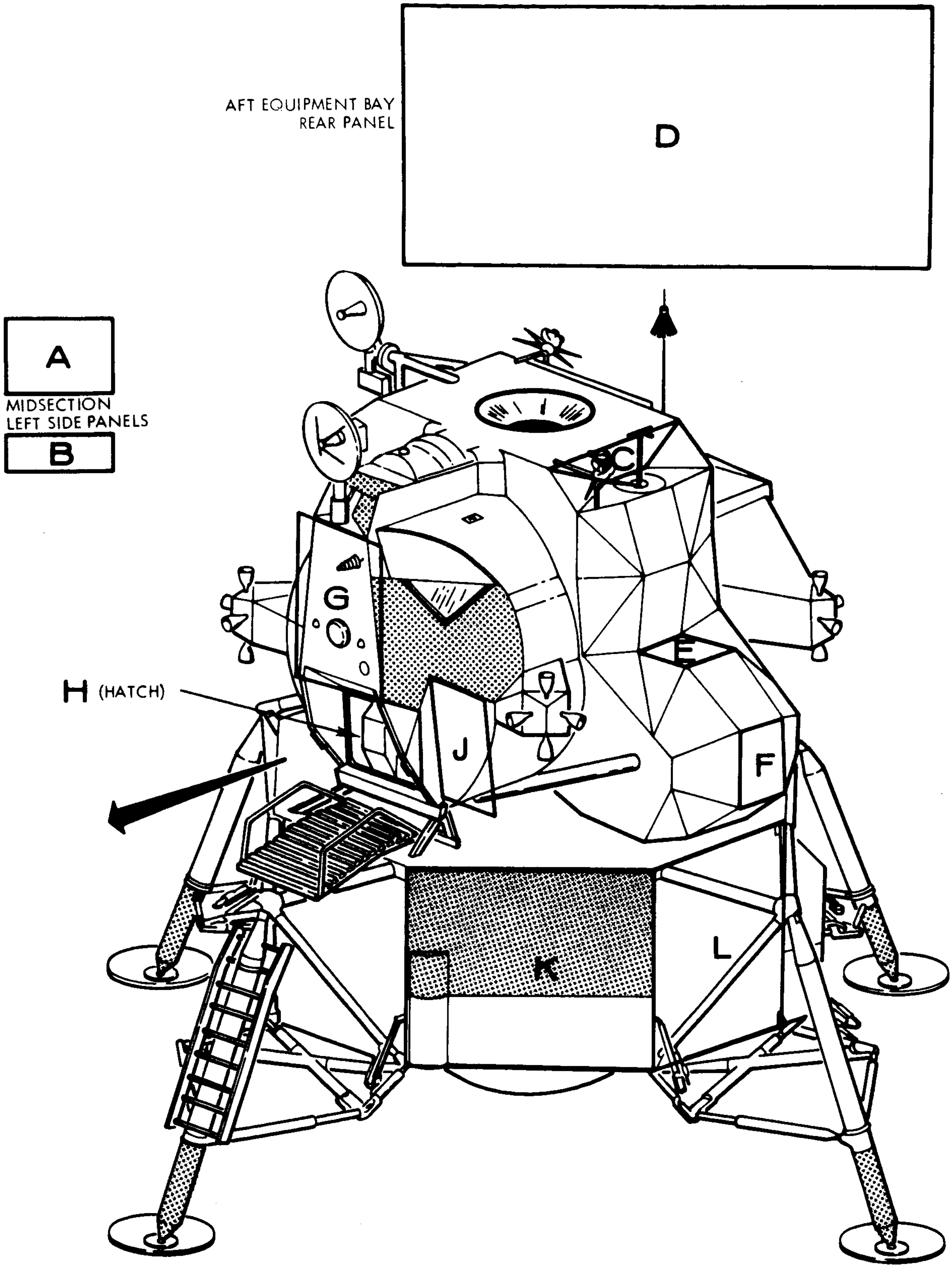

Figure B-1. Lunar Module Idealized Outer Panels

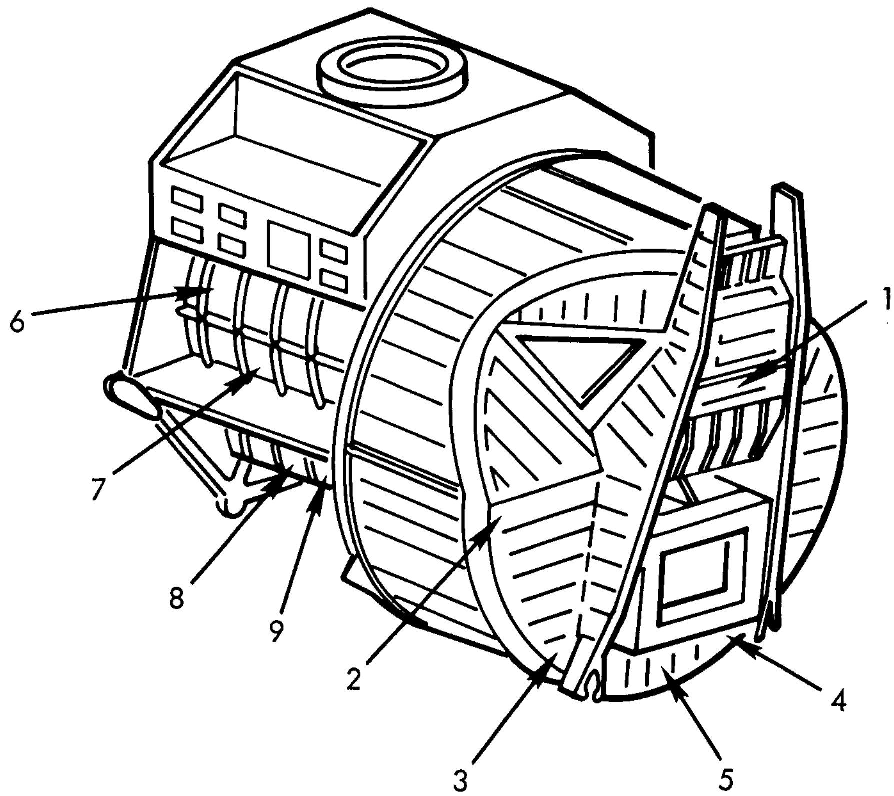

Figure B-2. Lunar Module Ascent Stage Inner Structure Panels

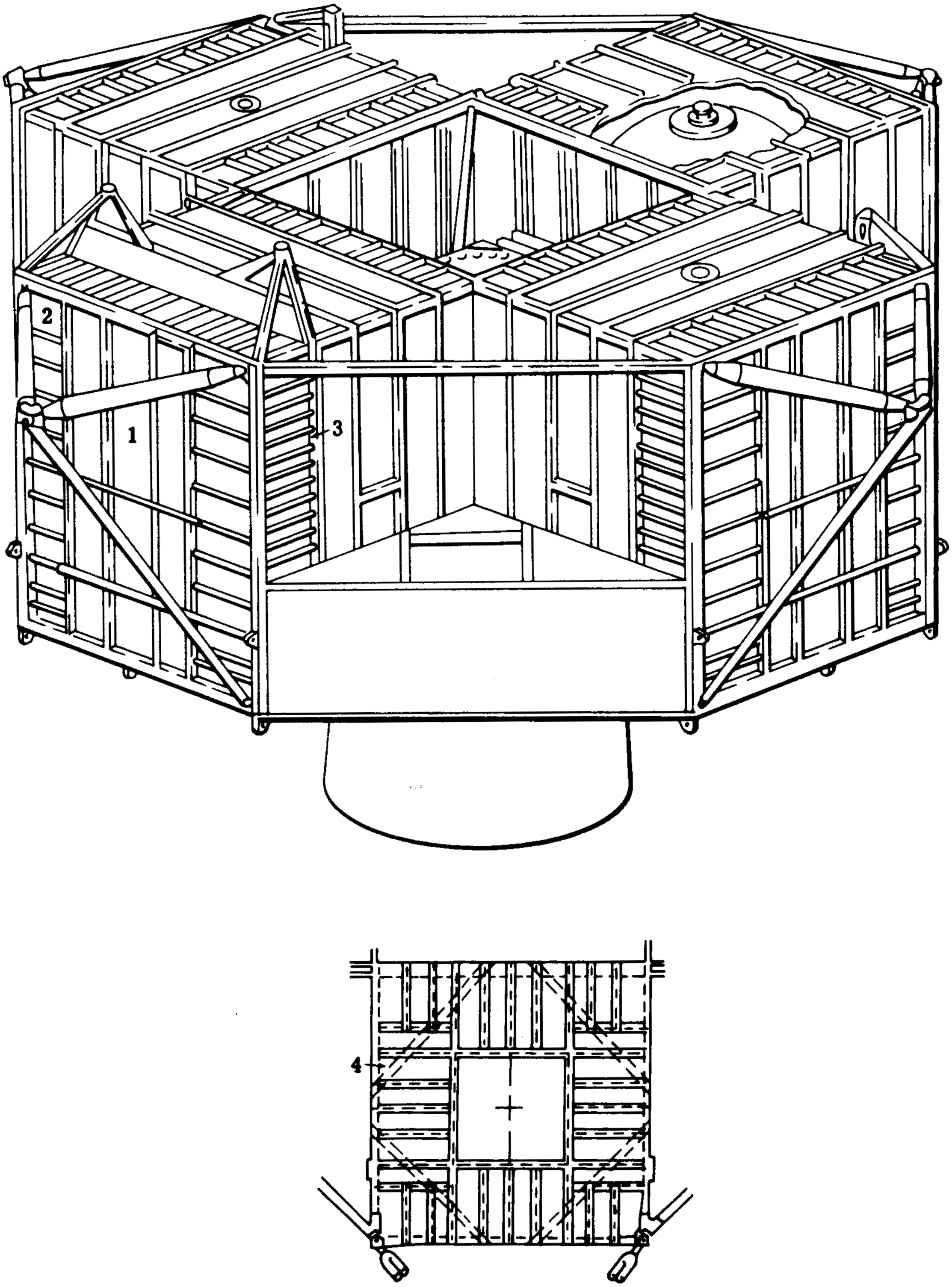

Figure B-3. Lunar Module Descent Stage Inner Structure Panels

REFERENCES

1. R. A. Lawrence, "Effects of Launch Vehicle Destruct Action on LM and LM Adapter for Mission AS-206," TRW 05952-6099-R0-00, 25 January 1967.

2. "AS-504 Preliminary Launch Vehicle Reference Trajectory, Volume 1," Boeing Company Space Division D5-15481, 13 July 1966.

3. "AS-504 Preliminary Launch Vehicle Reference Trajectory, Volume II," Boeing Company Space Division D5-15481, 13 July 1966.

4. "Apollo Mission Data Specification B Apollo Saturn 504 and Subsequent Missions (U)," TRW 2131-H002-T8-000, 1 March 1966. (C)

5. Extraction from a Douglas range safety report for the S-IVB/IB, Title and Number Unknown, 19 November 1965. This document extraction was obtained by TRW Task A-4 Task Monitor, C. F. Sengir, from the George C. Marshall Space Flight Center.

6. R. A. Lawrence, "Effect of Launch Vehicle Destruct Action on SM, LM Adapter, and LM Test Article for Mission AS-501 (U)," TRW 05952-6081-R800, 8 December 1966. (C)

7. H. J. Carpenter, et al., "Booster Rocket Altitude Abort Program (U)," TRW 4387-6004-T0-000, 4 July 1966. (C)

8. "Aerodynamic Data Manual for Project Apollo, NAS 9-150," North American Aviation Inc., Space and Information Systems Division SID64-174B, 1 January 1965, revised 1 July 1965.

9. "ARPS Penetration Studies, Volume I (U)," TRW 4170-6058-R3-000, December 1965. (S)

10. C. D. Faust, "Effect on Launch Vehicle Destruct Action on Service Module, Lunar Module and Spacecraft LM Adapter for Mission AS-503," TRW 05952-H161-R0-00, MSC Internal Note 67-FM-32, 3 March 1967.

11. R. J. Roark, Formulas for Stress and Strain, McGraw-Hill, 1954.